

THEORY AND ELEMENTS OF ARCHITECTURE

ROBERT ATKINSON
HOPE BAGENAL

VOLUME I
PART ONE: THE SIMPLER ELEMENTS

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OF ARCHITECTURE

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THEORY AND ELEMENTS OF ARCHITECTURE

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PUBLISHERS' NOTE

THEORY AND ELEMENTS OF ARCHITECTURE will be published in a series of volumes. Vol. I. deals with Architectural Elements and is divided into two parts—Part I. the Simpler Elements, Part II. the “Orders,” Domes, Vaults, etc., with chapters on Mouldings and Ornament. The two parts of Vol. I. form an introduction to Vol. II., the Development of Planning; and Vol. III., the Planning of Modern Building Types. Each of these sections will form a complete and separate unit.

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R. A.
H. B.

34 BEDFORD SQUARE
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NOTE ON THE USE OF REFERENCES IN THE FOLLOWING PAGES

For the sake of easy reference each chapter in this book is divided into numbered sections and the number (arabic numerals) is shown in conjunction with the number of the chapter (Roman numerals) on the top outer corner of each page as ii. 2. The reader therefore can tell at a glance where he is in the book and can refer rapidly from one part to another. References in the text to other parts of the book are either to a particular page as (p. 15) or to a whole section as (ii. 2), and both kinds are thus indicated on the pages. References to books are either to a list given at the end of each chapter arranged numerically according to their sequence in the text and referred to, as for instance (2) in brackets, or else to footnotes on the page where the reference occurs and indicated by small superior numerals without brackets, as for instance—" . . . other islands of the Cyclades.³" All the footnotes are referred to in the text by the small superior numerals. Appendix notes are specifically referred to in footnotes as *Appendix, Note 7*.

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THEORY AND ELEMENTS
OF ARCHITECTURE



[R. C. B.]

Chapter I

THEORY OF ARCHITECTURE

I. *AIM OF THE ARCHITECT*

THE aim of the architect is obviously to build well and simply under difficult and complex conditions. He cannot do this without knowledge, for, however talented he may be, no grown man can build—as once upon the nursery floor—without any reference except to his own fancy. Architecture carries with it the labours and fatigues of an active historical process, in which the needs and ideas of men living and dead, the materials available, and the temper of workers, are stubborn factors. For this reason it is both the most limited of the arts¹ and, at the highest, the most inclusive. Knowledge and the preservation of knowledge enters into it, as into civilisation itself. An architect who ignores what has been done in the past is in danger of wasting his time solving problems—structural and artistic—which have been solved already. Great men have built before us—of the same physical stature as ourselves, as acute, and using the same crust of the earth for materials. They have had opportunities of climate and material which

¹ Leonardo da Vinci, in the discussion on whether painting or sculpture was the nobler, said: “An art is weak in proportion as it carries with it the labours of the body [*fatiga di corpo*].” (Quoted by Pater, *Essay on Leonardo*.)

1. 2, 3. Theory and Elements of Architecture

we have not, and have made already the most valuable experiments. The principles of the Roman relieving arch, the Greek monolith shaft, the Tudor window, have direct applications in modern design. These and a hundred other "results" (in the scientific use of that term) are ours for a glance if we will use eyes and mind together.

Further experiments are continuously necessary, but a solid foundation of knowledge is required before we know whether our "new" ideas are indeed new and not old and long ago discarded.

2. MEANING OF "THEORY"

But when information is in process of being collected and knowledge begins—how apply it? How shall deductions from the experience of the past be used in new problems and new plans? Only by means of "Theory." Theory provides the link between the necessary knowledge and the activity of design. Theory is the first act of simplification in the mind, it is the planning of planning. A student can make no single design without having first drawn upon some source and linked and arranged a number of confused elements on some kind of a system. That system is likely to be compounded of his borrowings from others plus his native intelligence; but still it implies a criticism, a picture¹ of the relative factors, a recognition of the enemy chaos and of the fortress design, in other words a "theory." Theory is the framework of our whole thought: it is the wealth plus the critical power we bring to our job. Upon theory unconsciously depends our standard, our range, our direction of development.

"This training is worth while, these preferences are sincere. I will go in this direction and not in that."

Those are the kind of statements a student must be able to make, and to make upon sufficient grounds. His grounds are likely to correspond to his grasp of "theory."

3. INHERITANCE OF ARCHITECTS

Much of our knowledge must come from the past because architecture, like law and other fundamental activities, works cumulatively by a series of slow tests. Worth in a building is measured by the satisfaction, material and artistic, it continues to give over a series of generations. Thus a good concert-room, like the Gewandhaus at Leipzig, continues to please musicians and satisfy

¹ The word "theory" is derived from the Greek θεωρεῖν, "to look at."

audiences generation after generation, until it becomes a tradition and a standard in itself. Its design was not a matter of luck, its architects handled a tradition intelligently and handed it on to others. On the other hand, Street's Law Courts in London have not stood their test; though grand and dignified to the eye, they are an enduring handicap to the proper hearing of cases. The "Past" is full of buildings that have been and are still being tested, and the testing process is architectural history. History for the student of architecture is a record of experiments of which he cannot afford to be ignorant. The architect of to-day, however "modern" he may think himself, is equally part of the historical process. If he draws a dividing line between himself and his predecessors he blinds himself to the true nature of his work. He cannot help carrying on a tradition, but he can do so intelligently or unintelligently. Civilised humanity is past, present, and future, contingent and interrelated. We both benefit and suffer from those who have preceded us. Sir Christopher Wren said: "An architect ought to be jealous of novelties in which fancy blinds the judgment; and to think his judges as well those that are to live five centuries after him as those of his own time." (1)

4. ARCHITECTURAL HISTORY

History viewed thus becomes a vital study. The architecture of a period is the embodiment of its needs, fears, aspirations—it is the outer form of its civilisation. Great communities of the past living under certain conditions of climate, with these building materials and not those, have discriminated certain values, loved certain forms, have trained their faculties in a particular way, and set their builders certain problems. The builders had then to ponder and criticise and sum up all the factors in the scheme before them, in other words they had to design. In the study of a period we must discover the factors and then see how and with what success the designs were made, the problems solved. The life and the art of a period must be distinguished, and also how they have interacted upon each other. Then the architectural student may come to conclusions of his own differing perhaps from the orthodox conclusions of archæology. History for him is the study of peoples in their constructive moods¹—

(1) This number and others in brackets have their reference at the end of the chapter: the list forming a short bibliography of the subject. Other references and notes having superior figures are given at the foot of the page where they occur.

¹ Leonardo says: "Indeed man is nature's chiefest instrument, because nature is concerned only with the production of elementary things, but man from these elementary things produces an infinite number of compounds." (M'Curdy, *Thoughts of Leonardo da Vinci*, p. 30, Duckworth, 1907.)

1. 4. Theory and Elements of Architecture

satisfying wants, economising materials, adhering for reasons good or bad to old forms, inventing, contemplating, worshipping : it is the study of craftsmanship, the study of stones and climates, of the anatomy of structure, of the development of plans, of the lights and shades and various deliberate effects on the part of old artists.

Sometimes a particular building form and its treatment seems to characterise a whole civilisation. Then it is worth while making a special study of that form in relation to its epoch and pursuing it to quite remote causes. Systems of equilibrium in society and government are not unrelated to systems of equilibrium in architecture. Thus the sloped mud *wall* of the Nile valley, imitated or sculptured in precious stone, gives a clue to Egypt and to her apparent preoccupation with the tomb (iv. 5) ; the entrance to the great thirteenth-century culture of Europe is by the French *roof* (vii. 5) ; and through the "Anglo-Palladian" *window* we can get a glimpse of a particular English trait, namely, a love of the genius and climate of Italy and therewith some of the causes and failures of English Classicism (ix. 7). In the following chapters where a building element offers a clue of this kind and draws numberless threads with it, then what is known as "history" is touched upon.

Antiquity does not supply lessons only : it supplies the stuff itself—it supplies combinations of those elements of earth and mind which are still our problem. The combinations change, the essential elements remain the same. When—inspired by the prospect of the rich and continuous constructive genius of our kind—the student shall have learned the true nature of architecture, then he can walk at home in history. He will have his own reverences and his own disillusiones, and will be tempted to say with Sir Thomas Browne—"Now one reason I tender so little devotion unto relicks is I think the slender and doubtful respect I have always held unto antiquities. For that indeed which I admire is far before antiquity ; that is Eternity ; and that is God Himself." ¹

We must study modern buildings exactly in the same spirit as antique buildings, for we are ourselves in a historical period. It is good to be inquisitive about every modern building we come across—about its conveniences and inconveniences, and about its influence on those who live or work within it. In addition to satisfying wants buildings exercise a continual influence by their shape alone. Carlyle, after passing Chelsea Hospital a thousand times without apparently

¹ *Religio Medici*, Bohn's ed., 1852, vol. ii., p. 363.

regarding it, suddenly one day felt grateful to it and swore that its architect must have been a good man and a gentleman.

The spirit of buildings old and new is our concern.

5. *TASTE*

The study of architecture is not primarily the study of the intense personal vision of individual artists free to select their own forms, it is the study rather of race imagination experienced by men of average creative ability. Building has first to supply average needs and meet average tastes. It has for obvious reasons to do with the street and the man in the street. The architect stands in a fundamental relation to public taste quite different to the painter and musician : public taste is the basis upon which he must work and with which he must keep in touch. But that does not mean that he is its slave. He must direct and refine it.¹

Good taste is the expression of a real desire for quality in life and its forms, and often exists without any conscious effort after " culture."

An analysis of " taste " in England with direct reference to architecture will reveal some strange anomalies (ii. 6), but will reveal also ancient preferences that have very good reasons for existing.

Taste can be educated by familiarity with works of the first order, since such works embody most fully that sense of quality, as well as convey definite ideas.

But the architect in his own work will find that he must rely frequently upon sincere preferences of his own on points of pure æsthetics. Then he is testing his artistic instincts, and those instincts should have considerable freedom. It is essential that he should know his own " taste" and believe in it. Sincerity here is as important in architecture as in painting or music. But also there are decisions not concerned with pure æsthetics—decisions for instance as to what are the real needs and ideas of a client—which have to be made by an architect in the course of design. Such decisions, psychological in kind, require a trained

¹ In English the term " to refine " has had attached to it the suggestion of weakness : but without reason. Etymologically it means simply to make a thing *even finer*. Technically it has come to mean " to eliminate dross," that is to strengthen.

1. 6. Theory and Elements of Architecture

imagination and often test his whole range of sympathies and powers of observation—test, that is to say, his range as a human being. Architecture has continuously to do with life and art taken together, and the great architect, in a special sense, has to be a great human being.

Now it is because the study of “the Classic” in building forms (as in much else) has been found to train in human values and yet leave the mind—at such times of choice—richer and freer than other studies leave it, that it is still adhered to and reverted to in education. The “Classic” is not a matter of the antique only, it is primarily a standard of values, the result of the best and most universal experiments. We shall not be able to humanise steel-frame or reinforced concrete construction and make buildings in these or in any future material, logical and graceful, by any other essential process than that by which the Greeks long ago humanised marble masonry. We shall have to penetrate, as they did, to the roots of the problem, structural and artistic, and expend thought and talent upon it. Thus the building most truly “Greek” in a modern street may have no “orders of architecture” upon it; it may be nothing more than a steel-frame structure harmonised and vitalised, and yet be “Greek” in spirit.

A real knowledge of the roots of public taste is necessary therefore to the architect in order that he may understand how to develop and expand it when in the course of true design he sees new horizons before him. The man who best knows “the rules” is the man who best knows how to dispense with them later on.

6. REASON IN DESIGN

Facts should be gathered critically by the architectural student and hung upon a series of provisional frameworks, always expanding. The bearing such facts have upon essential design should be the key to their selection. The critical faculty therefore must be cultivated: it enters into architecture at all points. The test of sound “theory” is not only the ability to bring knowledge to bear on a given problem but also the habit of grasping the important factor in that problem and of keeping it dominant. To carry knowledge forward into design we must learn to put first things first and keep them there. A merciless logic is necessary to the architect in order that he may defy a thousand temptations and allurements. Design is a sequence from dominant requirement to “idea,”

from "idea" to plan, from plan to elevation,¹ from elevation to detail and ornament. (2) This reasoning process should be master throughout, ordering all questions of taste and tradition. Reason is sometimes at variance with preconceived tastes: new laws of hygiene and of physics recognised in a plan will alter familiar shapes. These shapes should not be altered out of caprice, but most certainly when reason requires, and then "taste" can be left to look after itself. But when the requirements of a building are still traditional then reason demands a traditional shape as in the case of a Roman Catholic church.

Tradition is crystallised reasoning which may or may not still be logical.

In the case of wireless stations, cinema halls, city garages, and many other modern buildings, conditions and requirements are still fluid and the designer then has full scope for his critical faculties and for penetration into the real and enduring solution of the new problem. The difficulties involved in a restricted site or in a special requirement may themselves give the key to a fine design: then the resulting building may appear "original" when it is truly rational. That is the kind of "originality" the architect should seek.

An architect's critical powers must be his resource in modern design for a special reason. In the past there were many powerful defining conditions in building which helped to create characteristic forms. Of these, local materials, and the traditions of craftsmanship that accompanied them, were the most helpful. The direction of development in design was generally towards the more economical use of a tried material (p. 76). The simple reaction of local needs and local quarries and timber yards produced simple building forms and left over a margin of effort for refining and improving them. But to-day no such simple reaction exists. World transport has entirely altered fundamental conditions of architecture in some fields. We have to build with what we can afford, and materials at a distance may be cheaper than those near at hand. What then are the limiting conditions that now help to define form? They are economic and they are scientific. Economy of cost within limits is wholesome but should be studied in relation to the future as well as the present requirements of the building. Hygiene is constructive and helps to compensate for the absence in modern design of the factor of local material. Modern requirements in cleanliness and sunlight set new limits to dimensions and prescribe new sizes of openings. Also,

¹ "Elevation" means internal as well as external elevation.

1. 7. Theory and Elements of Architecture

if properly applied, the laws of light and sound each in their own way regulate planes and surfaces and can mould a whole design. But these modern factors are not direct agents like the old, they act through the architect's mind, and must be resolved by him before they influence form. For this reason designing and drawing on paper is to-day more necessary than in ancient times: mistakes on paper due to a multitude of small requirements can be rectified. But the complexity of planning resulting from modern factors enormously increases the necessary mental effort. The simple wants and the simple plans of the ancients were by comparison easy to embody and refine. To-day an effort of sustained critical thought is necessary on the part of an architect before the business of building begins.

7. *UNITY*

Where then does the artistic problem come in? Is the 'whole of architecture a critical process? The answer is that all we have been discussing remains only the material out of which great works of art are to be made. The nature of the material is complex but since human thought and activity have caused it, human thought and activity can resolve and order it. The resolving and ordering must be done by the reason, and if a man feels he has no talent for essential organisation he had better not tackle architectural design. But the critical process must be followed by a synthetic process. We must gather from all fields in order to contribute to a design, but something must then happen which is far more difficult to explain. The design itself—the result of so many diversities—must be given character and coherence, a kind of life and meaning of its own. In other words it must become a "work of art," and must have "unity." Unity in architecture is not easier to explain than unity in any other art: but it is revealed by certain general symptoms such as the subordination of the parts to the whole, a continuity of scale, and a certain positiveness of effect. Unity in a building should be the natural result of the "idea" of the designer which (as we have said) should follow upon the discrimination of the dominant requirement. It should not be something imposed upon the elevation at the last stage, but should come naturally from the "idea" and should be the result of a true simplification at every stage.

But unity in city architecture is so important that it may be necessary at times to impose it artificially upon a design for the sake of the appearance of a street—for the sake that is of good civic manners. Hence the kind of standard

unity that can be got by the use of the Classic façade. But although architecture of this kind may be familiar and dignified yet it is not the greatest.

Other factors being equal a building which directly expresses its plan is greater than a building which fails to do so.

Similarly in the matter of construction it is often necessary for the sake of unity to mask the bones of a building and disguise its structure. Architecture of this kind is not necessarily "deceitful" if a total positive excellence is achieved by that means. But it will not be the finest architecture.

Other factors being equal a building which also expresses its construction is greater and richer than a building which fails to do so.

When an architect has developed the resources of his mind and has a useful reservoir of "motifs,"¹ he will find that his own personality will impose a certain unity upon his design. The personality of the architect comes of its own accord to contribute to "the artistic side" in architecture. But personality should not be deliberately emphasised: an architect should not haunt his building for ever afterwards. The impersonality of great architecture is one of its priceless qualities making for peacefulness and equilibrium—the special contributions of architecture among the arts.

Unity is necessary, but obviously the unity of a building having a rich imaginative plan properly embodied will give greater satisfaction than the unity equally complete of a poorly planned building. Plans can give or fail to give to the architect nearly as much pleasure as buildings themselves. But it is again difficult to explain wherein lies the art of a good plan, and again there are certain symptoms. A good plan has an underlying harmony between all its parts and has also a contrast between one group of parts and another. The more subtle the harmony and, coincidentally, the bolder the contrast, the more alive and pleasure-giving will the plan be. Exactly the same symptoms hold in the designing of patterns. We shall see that the Romans in the plans of their great buildings show these symptoms and likewise the Greeks in their elevations, their mouldings and ornament. The lesson of the good pattern can be followed through the history of architecture and is to-day equally important.

¹ "Motifs." The results of the structural plus artistic experiments of the past have become embodied from time to time in recognised forms—as, for instance, relieving arch over lintel. These are termed motifs.

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8. THE STYLES

If an artist is wise he expresses himself in a language sufficiently familiar and uses a vocabulary as rich and simple as possible. Style¹ then is the grace and gust of his language and the ease with which he makes us understand difficult things. "Mastery," "economy," "completeness," enter into our meaning of the term. In this sense style—as something athletic—is more generally relished by Englishmen in field sports than in the arts: but it applies exactly to good building. A bright, neat, modern school building may have true style and give a new air to a dull street. But there is another and confusing sense in which the word is used in architecture—it is used for the language itself, for the instrument of expression. The great "styles" are languages of form (2) and each at one time was a familiar language. Like all languages they are systems of simplification and the terms "Classic," "Gothic," etc., are only labels for the chief classes of these systems. Craftsmen, priests, and artists have contributed to each language and each has its own range of values.² Each has its own talent of omission and of emphasis. To-day these languages are not dead—they speak continuously from monuments that all men are at one in preserving and give continuous pleasure. We shall always be liable to Gothic "revival" while our cathedrals stand on our soil, we shall always be liable to Classic "revival" while we fight against fog and have in our streets the least sunlight to remind us of Italy and Italian cities (ii. 6). But they are languages which cannot be constantly used with unchanged idiom in changed surroundings. We speak English to-day but we do not use the idiom of Chaucer. In our architectural languages we have to select and add, and admit new terms and expressions, yet all the while keep a clear grasp of the original structural and climatic meanings.

9. SOME DISTINCTIONS TO BE DRAWN

Architecture has a constant reference to life and to art taken together: the architect (unlike the painter) has actually to make the things whose forms when related shall be beautiful. In the study of architecture, therefore, if we attach all the importance to the things alone, or again to the shapes alone, we shall be in danger of mistaking the part for the whole. The student of architecture

¹ The term has a definitely literary origin. "*Style*, a pointed tool for writing, a mode of writing." (Skeat.)

² Architectural forms do not seek to represent or imitate natural forms as in painting or sculpture, but have their own convention, as in music.

must learn constantly to distinguish without separating. A certain duality of view is necessary from the beginning. He must be able to pass freely from facts to forms, from the scientific to the artistic attitude.

The first distinctions generally agreed upon are that architecture supplies both material needs and spiritual needs. (3) Architecture is partly the fulfilling of the commonest conveniences and partly the expressing of ideas about eternal things. Both enter with equal importance into design and the history of design. We shall see for instance (vii. 2) how the collecting of rainwater from the Roman roofs is related to the planning of Baptisteries. In architectural elements—walls, doors, columns, etc.—both kinds of need are continuously related. This we shall refer to more fully in the next section. They have to be distinguished and yet considered together.

These first distinctions can be stated as follows:—

“Well Building hath three conditions, Commodity, Firmness and Delight.”(4)

This is a phrase of Sir Henry Wotton's but other architects have arrived at the same generalisation.¹

In *Commodity* (or accommodation) is included the activities called planning; in *Firmness*, structure and materials; and in *Delight* all the artistic element both of design and craftsmanship. It is useless to exalt one of these three factors above the other two. The nature of architecture involves all three and a building must be finally criticised on three grounds. It cannot be denied that a building like the Alhambra is neither firm nor well constructed, yet it conveys delight, and Beauvais Cathedral is beautiful but insecure (p. 243). Street's Law Courts, though unfitted for the purpose of hearing cases, are impressive architecture. But the delight and the impressiveness are not pleas for instability or inefficiency. We can classify commodity and firmness under material needs as the “functional” or “utilitarian” side, and “delight” under spiritual needs as the artistic or æsthetic side. But again one side cannot be stressed in architecture above the other. They must be distinguished but not separated. The architect must study both and supply both. If in the solving of any problem he finds that the one follows naturally upon the other then so much the easier for him. If

¹ For instance Vitruvius says: “Public Buildings . . . should possess strength, utility and beauty” (Book I., Ch. 3). Wren says: “Beauty, firmness and convenience are the principles.”(1) Sir William Chambers adds *health*. He says: “Its purpose is to erect edifices in which strength and duration shall unite with beauty, convenience and salubrity.” (*Introduction to Treatise on the Decorative Part of Civil Architecture*, 1759.)

in the course of design he shall find that the satisfaction caused by function and by shape are at bottom parts of the same experience then the happier he, but the student should know that many of the acutest minds have found them divided by a gulf.

10. ARCHITECTURAL ELEMENTS

It is possible to divide any building into a number of component parts, recognised as distinct, and having distinct names from the earliest times. These parts are: *wall, roof, pillar, door, window*. To these simpler parts may also be added others derived or invented in response to further needs, namely, *arch, dome, vault, column* (or *shaped pillar*), *staircase, flue, fireplace*. They can all be grouped together and thought of as a series of *elements*, together forming a kind of vocabulary of architecture.

Architectural elements, themselves simple, are capable of elaborate combinations in the study of which the primal meaning of the parts is apt to be forgotten. A window at its most elaborate should retain something of the feeling of a hole in the wall, a door of something able to open and shut (see the head-piece to this chapter). Simplicities of this kind are part of the emotion capable of being conveyed by architecture and this has been recognised by other artists besides architects.¹

The Egyptians gave proper names, not only to whole buildings, but also to parts of a building, for instance to the doors of temples. This suggests that they personalised the parts as well as the whole building. The modern architect should not impoverish his work by ignoring those first meanings always available and delightful.

It is not possible here to examine exhaustively the origins of architectural elements and of their first meanings. Modern research seems to show they cannot be referred wholly to motives termed utilitarian, or wholly to motives termed religious or symbolical. Each architectural element can be shown at one time or another to have fulfilled both kinds of role. A wall was first perhaps a protection against wind or a support to a hut roof, yet how early in the world's history does it not appear as a writing tablet, a picture gallery, or an

¹ In a play of Maeterlinck's, a single large door closed between two human beings is the motif of the drama. Gordon Craig, in "Towards a New Theatre," bases many of his designs on the simplest architectural elements and speaks of "this feeling about architecture in my art." Concerning the *staircase*, he says: "And among all the dreams that the architect has laid upon the earth, I know of no more lovely thing than his flight of steps leading up and leading down."

offering to a god. The fireplace or hearth has a long sacrificial lineage. Authorities still differ as to whether the columns of an Egyptian naos were first constructional or first votive. Now the student of architecture cannot always avoid controversies of this kind; but he can stand on sure ground when he refers them to the living psychology of his own art. Architecture, as we have said, is concerned both with the material and the spiritual needs of men. The architect argues from his own experience that "primitive man" (that widely canvassed individual) built a house for his god about the same time as he built a house for himself: that the building of his hut helped him against one kind of fear, and the building of his shrine against another kind of fear: that in each also he found scope for those "human" or creative instincts which are able to work side by side with, and eventually change and subdue, the breed of fear. Looking around him, the student of modern architecture sees wealth and thought spent upon houses, flats, hotels; but also upon war memorials, churches, masonic temples. Which of these two classes of buildings is the more fundamental, the more *original*? The question has only to be asked to show its superficiality. The two classes are equally part of humanity, and the architect need not join in conflicts as to which is the more fundamental. He can distinguish each, the "utilitarian" and the "spiritual," without separating them in his mind.

The elements of architecture, therefore—walls, roofs, doors and the rest—have all to be regarded from both points of view, both structurally and functionally as parts of the building and also æsthetically as parts of a work of art. In this way, then, distinguished without being separated, they will be treated in the following chapters.

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NILE, THE FATHER

Chapter II

CLIMATE AND BUILDING MATERIAL

1. PROTECTION

CLIMATE sets men their first and enduring problems in design—the problems of protection. These can be summarised broadly as of three kinds, (i) protection against the direct rays of a powerful but not devastating sun, (ii) protection against rain and snow, and (iii) protection against extremes of heat and cold, often occurring in the same region. To these kinds of protection correspond roughly certain elements in building, namely, (i) the covered colonnade, (ii) the sloped or “pitched” roof, and (iii) the thick wall and vault. Now the covered colonnade gives horizontal and vertical planes, the pitched roof gives the inclined plane, and the thick wall and vault give the intersection of cylinders and planes. Thus climate tends to determine essential shape and it is true that in any region the relative suitability of these classes of shapes, alone or in combination, will determine among other factors the first origins of style.¹ It is not true that the great styles are due *wholly* to climatic conditions—other more volatile

¹ A good instance of climate directly influencing simple design without any apparent foreign style influence to modify it, was observed by Livingstone on his Manyuema expedition in Central Africa in 1869. See *Appendix, Note 1*.

and wilful factors, which will be considered later, are just as important—but in the complex of forces that crystallises out into architecture, climate is the first and requires a first understanding. Let us consider in this connection the great facts of climate that have obviously contributed to European civilisation.

First among these are the many gifts to men from the soil and climate of Egypt. The narrow valley of the Nile, traversing the rainless Libyan desert, had the advantages of a completely dry and bright atmosphere and, at the same time, a plentiful water supply from the annual flooding of the river. A part of the delta only has a slight rainfall, but such is the general dryness of the air that even in marshy districts malarial fevers are rare. The result is a natural environment, warm and brilliant but not enervating. When the mud of the Nile was made into blocks the sun baked them into bricks in a few days. Herodotus first said that the Egyptians produced crops with less toil than any other people,¹ and to-day three successive crops can be harvested in a year off the rich alluvial soil. These advantages left the Egyptians much leisure and tended to produce a leisured class. As early as the period of the Old Kingdom they had private gardens and amid flowers listened to musical entertainments. (1) Flower-culture and music are arts that can easily become dissociated from their ceremonial or utilitarian origins when a certain stage of civilisation is reached and are evidence of the emerging of the “contemplative sense.”² The Egyptians built river-side houses of mud bricks with flat roofs or with open colonnaded upper stories (Fig. 1) set within the garden enclosure, from which they could see life as a river pageant having the desert and the tombs of the dead as a background. Also from the roofs of such buildings they observed the stars and were the first to measure the length of the year³ and construct the calendar (B.C. 4241).

Now we shall see that owing to a variety of reasons (iv. 5) the shapes of these flat-topped mud-brick houses, the homes of their labours and observations, were

¹ Herodotus, Book II., 14.

² By the “contemplative sense” is meant the sense that enjoys forms, colours and proportions, for their own sake apart from any uses attached to them: the sense for instance that enjoys the rose apart from the fact that it may win a prize at a rose show. The English word *contemplate* suggests both observation and meditation: its meaning as given by Skeat is as follows: “Contemplate (Latin) from the past participle of *contemplari* to observe, consider; used at first of augurs: derived from Latin *con* (*cum*); *templum* an open space for observation (by augurs).”

³ Practical reasons connected with husbandry probably stimulated and perhaps caused the Egyptian study of astronomy. For instance, it was desirable to know the exact length of the year for purposes of sowing, and of recording and anticipating the flooding of the Nile, especially if several crops were to be had in a year.

imitated by them in hard stone as temples or homes for the gods, and as tombs for the dead.

From Egypt and her beneficent climate came the architecture of the wall

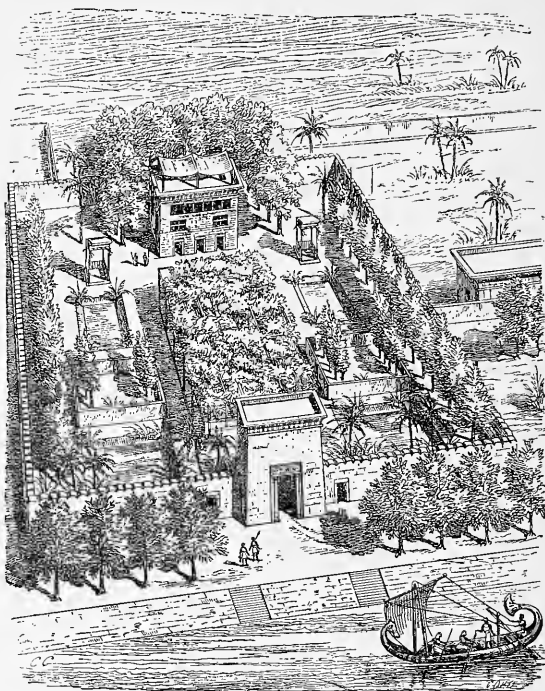


FIG. 1.—HOUSE AND GARDEN OF AN EGYPTIAN GENTLEMAN OF THE OLD KINGDOM. (*After Chipiez.*)

and of the colonnade, giving the horizontal and vertical planes and the “square” shapes ¹ (Fig. 2).

The sea board of the Mediterranean had a climate both temperate and

¹ The fact of the pyramid and obelisk shapes and of the slight slope or “batter” given by Egyptian builders to their walls will be discussed later (iii. 1 and iv. 7). The characteristic shape of the developed Egyptian house and temple is admitted to be “square.”

brilliant in which, like the Egyptian, men could live the greater part of their lives out of doors. They were not as free from rain as were the Egyptians, and as a consequence we find that the Cretans laid their roofs to a very slight fall (*see* Fig. 90), and the Greeks gave to their building roofs having a distinct, though low-pitched gable. As the rain fell from the eaves along the flanks of these gabled buildings entrances tended to be placed at one end. Thus came about the simple but characteristic low-gabled rectangle of the Greek building (Fig. 3), a parent shape that runs through history (p. 202).

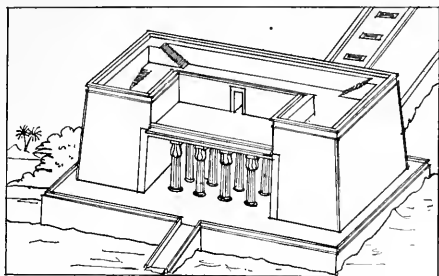
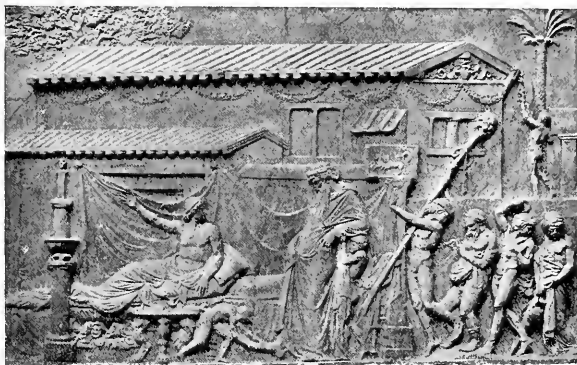


FIG. 2.—A GATEWAY TO AN EGYPTIAN FUNERAL TEMPLE. (*After Borchardt.*)

Now in both the Egyptian and mediterranean cases one result of the bright light and of the excellence of the climate was that men had not only leisure to



[By permission of the British Museum.]

FIG. 3.—RELIEF ENTITLED DIONYSOS AT THE HOUSE OF ICARIOS SHOWING A LOW-GABLED HOUSE IN THE BACKGROUND.

contemplate, in the sense of that word defined above, but had also forms and colours worth contemplating. Men not only conducted affairs and lived largely out of doors in a physical sense, as illustrated in Fig. 3, but also thought and

II. I. Theory and Elements of Architecture

mused out of doors.¹ The "artists" and "thinkers" were able to grow old in the open air. They used their eyes and thought a great deal about what they



FIG. 3a.—ORATORY OF ST GALLARUS, NEAR KILMALKEDAR, KERRY.
(From Dunraven's *Notes on Irish Architecture*.)

saw, and thus they came to criticise buildings as much from the outside on account of their shape and ornament as from the inside on account of their convenience.

This kind of criticism from outside in a manner leisurely yet acute, and the detachment of mind that it produces, suggests the origin of what we now call "the æsthetic attitude."

But when we turn from the Nile and the Mediterranean to our Nordic and Celtic ancestors we come to a different range of necessities and to less leisure.

¹ Cf. "From the portico the Roman civilians learned to live, to reason, and to die" (Gibbon, Ch.

44. By "civilian" is meant a student of law and public life). Compare also such expressions as "the stoics"—those who learned from Zeno under the *stoa* at Athens, and the "garden of Epicurus."

Northern builders leading harder lives in cold and wet weathers were familiar first with conflict and with dire need. The building is required first to protect women and infants and must actually preserve life. The interior is much more important than the exterior. Afterwards contemplation and ornament are related to these pre-existing necessities. The light was bright when snow was on the ground, but at other times was not comparable to mediterranean light for the enhancing of shapes and colours out-of-doors. Thus instead of a painted colonnade we find the characteristic northern shape to be some kind of a roof, often springing directly from the ground, "such as the Irish oratory" (Fig. 3a), or the English roof on crucks (p. 219) (Fig. 4),

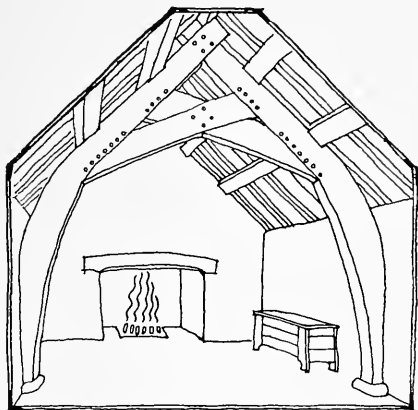


FIG. 4.—EXAMPLE OF ROOF ON CRUCKS.
(From Hughes & North. *Old Cottages of Snowdonia*.)

and having the steeply pointed shape able to throw off the rain and snow.¹ This steep roof or wedge shape has a great vitality of its own and in all temperate climates can be recognised as a rival to the mediterranean shapes. The height or steepness of the roof became a matter of pride and was early noticed by poets: ornaments and metal sheets were applied to it by early builders as to the most conspicuous and beneficent part of the building² (vi. 5).

A third climate which has influenced civilisation is that of Mesopotamia: here both the sun in the summer and the rain and cold in the winter are serious enemies.³ The sun as an enemy is difficult for northern people to realise but it explains a large part of architecture. It requires protection by mass: every inch given to the thickness of a wall is useful in a climate where coolness within doors depends on the resistance to heat of the whole mass of the building. This

¹ The exception found in the Swiss chalet is examined in ii. 9.

² *Beowulf*, a poem by a sixth-century Saxon writer, has the following passage: "... he went to the hall, he stood upon the steps, he saw the steep roof variegated with gold." (*Beowulf*, translated by J. M. Kemble, 1837, p. 39.)

³ An example of the influence of climatic extremes on common house design in Khurdistan is given in iii. 5.

II. 2. Theory and Elements of Architecture

is common also to Egypt and in a less degree to the Mediterranean ¹ but increases in importance with the verticality of the sun's rays. Thin roofs are useless: the mass requires to be overhead as well as at the sides. In Mesopotamia, therefore, where there were plenty of mud bricks we find thick walls and square shapes as in Egypt, but since neither timber nor long stones were abundant we find also that the mud-brick construction was carried overhead in the shape of the dome and the vault (iii. 5)—at first small in size and then larger until the great spans and the great thicknesses of Ctesiphon (Fig. 4*a*) and of Sarvistan were arrived at. The mass of these walls and vaults equally protected against the sun in summer and the severe cold and storms in winter: the rain and floods were countered by the use of bitumen as a covering to flats and by a fine system of drains. Hence from Mesopotamia came the vault and the dome in combination with the square shapes (Fig. 26).

This method of protection against savage extremes found in Mesopotamia and Persia and analysed more fully later on (iii. 5 and 6) can in turn give to the western student a clue to the great Asiatic styles farther east.

2. INFLUENCE OF THE HEARTH

Upon climate also depends the importance of the hearth and its use for comfort as well as for cooking. The tradition of a hearth may modify planning, in the same climatic region, as can be seen in comparing the Minoan plans without hearths to the Mycenaean with hearths. But in northern climates the hearth tends to become significant of a change in essential conditions and in the spirit of men. Climate changes the mood and character of a race migrating northwards out of the parent sunshine and driven to compensate itself as best it can for lack of light. The hearth then becomes the "focus" ² of the dreams which men substitute in long dark winters for direct sensuous enjoyment. This also influences their religion. Architecture reflects the difference between the races that worship their gods in the open air and those who are driven indoors to worship. But the greatest change is felt by the type of mind we call the "artist." He cannot so easily, in northern countries, contemplate shapes and colours in the open air, paint on walls in the sun, or refine still further the shape of a shrine. Instead, in the intervals between more urgent activities, such as fighting or

¹ In Florence, in the early hot months, a cool wind can be felt blowing into the street out of the doors of palaces such as the Strozzi, whose walls consist of extremely thick masonry.

² Focus, in Latin, means hearth. See footnote p. 22.



FIG. 4a.—CTESIPHON. REAR VIEW OF THE PALACE. (*From Dietlaff.*)

II. 2. Theory and Elements of Architecture

hunting, he sits in the firelight and carves the handle of a hunting knife or traces an ornament upon a pot. Such objects come easily to hand, and on them he can spend his fancy. Thus in hard climates art and ornament tend to be connected directly and frequently with objects of utility. The utensil or the weapon rather than the shrine becomes the characteristic refined object, and the art expended on it has a constant reference to its use or its function.

The logic and skill of the maker of beautiful weapons and utensils—the skill of the smith—suggests the origin of what is now termed craftsmanship and the craftsman's attitude to art.¹

Also the fire upon the hearth—the substitute for the sun in northern winters—must be visible.² The Romans in Britain had brought with them from Italy an elaborate central-heating system, known as the *hypocaust* system, yet they also used centrally placed braziers, and they appear, from the plans of houses at Silchester, Bignor, and Colerne, to have had open hearths as well.³ The objection

¹ The distinction here drawn between the two attitudes—the mediterranean or contemplative and the nordic or craftsman's—is not to be taken rigidly, it is only a first framework for our thought. These attitudes are suggested as the characteristic, not the whole content, of each of two distinct groups. We must in both groups admit much of the opposite. Thus in the nordic group we must admit the existence in Russia and Scandinavia of colours applied to the *outsides* of buildings for the sake of appearance only and for their enhancement in the brilliant reflected light of the snow. And in the mediterranean group it is important to remember in Homer the special sense of beautiful and elaborate craftsmanship everywhere displayed, and the prominence of the god of the forge, Hephaestus or Vulcan, who is indeed the husband of Aphrodite. Beautiful craftsmanship existed at all times as a background to Greek art. Also in Homer columns (on the exterior of a building) are mentioned rarely as compared to "high roofs," and a custom common to the northern and many primitive cultures is found in Homer, namely that of covering a building with sheets of metal (*Odyssey*, vii. 37. House of Alcinous). But the Dorian Greeks are generally believed to be a nordic people come south; the impression given by Homer is of a people with a new and youthful relish for light and for brightness. The adjectives "bright," "shining," and "polished" are frequent: the sense of surface brightness is everywhere in the *Odyssey* and *Iliad*. The impression conveyed is of a race with a strong culture of its own but sharpened to a relish of surfaces and textures by new and brilliant climatic conditions—conditions which in the course of centuries were to modify original forms. The Homeric conception of Olympus, or the dwelling place of the gods, is the conception of a people who take conscious pleasure in light. It is explicitly described in the *Odyssey* thus:—

"Not by winds is it (Olympus) shaken, nor ever wet with rain, nor doth the snow come nigh thereto, but most clear air is spread about it cloudless and the white light floats over it." (*Odyssey*, vi., Butcher and Lang, p. 93.)

² The existence of the "stove" for more efficient heating, found at an early date in Russia and other countries where extreme cold had to be countered, will be discussed later.

³ *Archæology*, xvii., p. 213; lv., p. 240; lviii., pp. 20, 26, 417. *Arch. Journ.*, xiii., p. 328. See also Ward's *Romano-British Buildings*, p. 272. The Italian winter is short but often severe. The open hearth is often referred to in Horace as (*Odes*, i. 9), "dissolve frigus ligna super foco large

to a central heating system alone, and the need of the open hearth, still continues to-day because it compensates for a deep privation—the privation of sunlight. But the usual position of the hearth in the centre of the hall where the greatest number could sit round it necessitated a flue or funnel, or else an increased height of roof in order that it should not catch fire.

Thus a number of facts directly due to climate tended, in the north, to emphasise the pointed shapes and the inside of the building. Externally they were capable, as we shall see in the chapter on roofs (vii. 5), of being developed into the finest aspiring images of a joy that was “not of this world”—a joy of compensation. In other words the cottage on crucks could be developed into the Gothic cathedral.

3. CHARACTER OF THE LIGHT

It is also most important in the history of design to consider in any region the character of the average light. In this respect climate has continually modified the development of architectural shapes. Generally speaking, fine architecture is the result of bright light illuminating a fine material. In countries where shapes are not seen they are not enjoyed and improved upon. And in addition to the quantity of sunshine it is equally important to examine the reflecting power of the wall surface. The aim of the architect should be to design for brightness. A white matt surface will reflect as much as 84 per cent. of the light falling on it. (2) Conceive for a moment and compare a building of alabaster and another exactly similar of coal. The chief difference between the two will be that the one will be generally visible and the other frequently invisible. But there will also be a difference between the two in the quality of the shadows cast and in the surfaces seen in reflected light. The common Classic scale of mouldings used to-day indiscriminately all over the world came about by refining lines of light and shadow originally cast on walls either of bright lime-washed plaster or of marble by the mediterranean sun. The brightness and sharpness of the material and the quality of the sunlight combined to give conditions suitable for minute variations and refinement by the contemplative mind. To-day in Greece new walls are frequently reduced in brightness by a coat of ochre in order that they shall be comfortably seen;¹ and it is likely that exactly the

reponens.” This means probably that Horace at Tivoli had open hearths and a hypocaust as well for winter weather. The Greek winter too was short and sharp, and there are references in Alcaeus to piling high the fire in winter.

¹ In scientific terms the Greeks reduce their surface from “ivory white” having a co-efficient of reflection of 77 per cent., to “ivory tan” having a coefficient of 56 per cent. (2)

11. 3. Theory and Elements of Architecture

same process was followed by the ancient Greeks both for plaster and marble surfaces.¹ But a misty sun and a rougher surface will not reproduce the art of the original and may cause a complete loss of value. Thus the English sun and a smoky weatherworn limestone reflecting only some forty per cent. will not give the Greek Doric Order. The Greeks themselves were not content with limestone as a surface, but in the Doric temples, for example at Selinus, Olympia and Aegina, covered it with a plaster in order to get a smoother and more reflecting surface (iii. 2).

Equally important is the amount of light reflected upwards from the ground. The mediterranean sky is a dark blue and diffuses very little light, the rays of the sun are projected through a transparent air and, on striking the surface of the earth and its buildings, a brilliant diffusing occurs. Thus in any mediterranean building on the two sides in shadow there is a considerably greater light striking upward from the ground than from the blue of the sky above,² and shadows can frequently be seen above string-courses and projections instead of below them. This means that away from the direct sun, soffits or under sides, frequently receive more light than vertical surfaces, and are therefore more worth ornamenting.³ The sides exposed to the sun have vertical surfaces exceedingly bright, and dark cast shadows which, however, grow paler nearer the ground owing to the intense reflected light, which in addition lights up all soffits. Thus the reflecting power of the ground plane is always as important a factor as the light itself. Generally speaking an upward striking light enhances architectural forms giving a glow in the shadows. The Taj Mahal in India was deliberately designed with a reflecting plane all round it in the shape of a white marble terrace, the result is a design not in lights and shadows contrasted but in a variety of lights having different tones. This can also be seen roughly in the modern Greek building illustrated in Fig. 5a. Now in a northern temperate climate like the British Isles the

¹ Vitruvius (B.C. 15) writing of "natural colours" says that ochre "is discovered in many places, but the best is the Attic sort," and adds, "Hence the ancients used abundance of ochre in their finishings." Book VII, Ch. vii.

² This can be tested easily in the Pantheon at Rome; if a man stands under the eye of the dome, but out of direct sunlight, he has two shadows on the floor behind him: one very faint shadow is cast by the blue sky space in the eye of the dome and another sharper shadow is cast by the brightly lit wall area on which the sun, itself invisible, happens to be shining. In other words the brighter source is the reflecting wall surface not the blue sky area.

³ A good example can be seen on the sides in shadow of the Victor Emmanuel Monument in Rome, built of white marble unreddened in tone. On these sides the vertical surfaces are bluish from the sky reflections and all soffits are golden from the considerable light striking upward. The sides exposed to the sun are too blinding to be analysed and demonstrate the value of the coat of ochre used by the Greeks.

total light is actually less,¹ but the normal sky reflects and diffuses a relatively greater proportion. The blue is lighter in colour than in the south and the white clouds have considerable sky brightness. This means that light is shed vertically downwards from a relatively large overhead source rather than projected at an angle from the relatively small intense source at the sun's disc. At the same time the ground does not act as a powerful reflector but often seems to absorb light, and in consequence shadows are darker and heavier and soffits or under sides have less value. In France and England a Classic design requires a bright paving beneath it, as in the garden front of the Petit Trianon (Fig. 5),

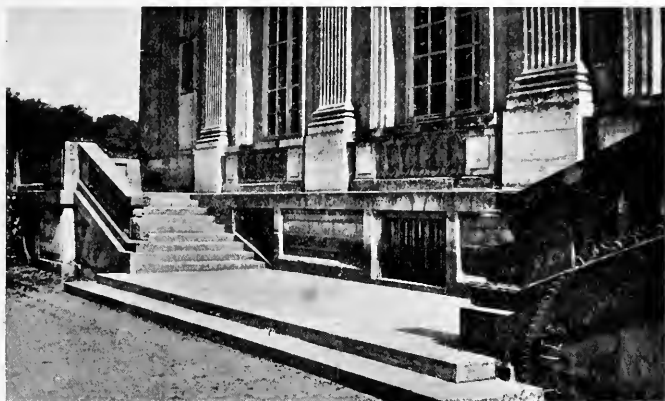


FIG. 5.—VERSAILLES. PETIT TRIANON, PAVEMENT ON WEST FRONT ACTING
AS A REFLECTOR.

[H.B.]

and porticoes should not be placed facing north. Vertical surfaces and roofs have relatively more light, and soffits relatively less, than in the Italian case. We shall see later how logical designers like the Greek and Gothic builders evolved opposite types of cornices in response to these climatic conditions.

The amount of water vapour present in the atmosphere, and the relative diffusing from sky and ground, influences the quality of the light as well as its quantity. On the quality depends the value of colours in the open air (ii. 5) and also the paleness or heaviness of shadows in the sculptor's sense. England,

¹ An ordinary photographic exposure metre, when placed in direct sunlight at noon in early summer, will register about twice the brightness in Italy as in England.

Ireland, Italy, France, Scandinavia, and North America are all said to differ in their climates in regard to colour values and the quality of shadows. The surfaces of the characteristic building materials in each country also increases these differences (ii. 8), but it is important that they should be recognised by architects when adapting or developing building forms. They cannot be properly studied in photographs. In the British Commonwealth European styles are often maintained in remote parts of the world for reasons of sentiment. British builders often show considerable ingenuity under new conditions in adapting plans and structures to meet changed needs in comfort and hygiene. But the changed climate also requires an artistic change on the grounds we have here suggested. The quantity and quality of the light, if properly studied, must modify the orthodox Classic or Gothic, or convert to quite other forms. Where there are new climatic conditions new styles ought to arise.

4. PENETRATION OF LIGHT

The penetrating power of light directly influences the design of interiors and indirectly therefore the design of exteriors. In Egypt, Greece and Italy, a single door-opening, or a few small windows, will serve to light a whole hall, and this fact has influenced the character of sacred and domestic interiors in those countries. In more northern climates the necessity for light is in conflict with the necessity of keeping out the cold, and we find through the Middle Ages a development of shutters and glass openings combined together in domestic buildings (ix. 4). Within the Gothic church, tracery and stained glass developed naturally upon the brightest field presented to the eye—namely, the window openings (ix. 1). But when French Gothic was imitated by Spanish builders the characteristic Gothic window was soon found in Spain to admit too much light and heat. At Avila Cathedral many Gothic windows were walled up. The smaller late Gothic churches in Spain are almost without windows.¹ We shall see also (ix. 7) how English eighteenth century architects followed Italian window design and how their buildings suffered in consequence. In modern practice English architects recognise that they have to design for a shallow light which will not penetrate far inwards from the window openings, while American and Italian architects have a strong light which will light interior offices adequately through a series of “borrowed lights.” Upon such considerations depends the

¹ Street's *Gothic Architecture in Spain*, 1865, p. 111. See also Historical sketch of Spanish Art by C. Justi in Baedeker's *Spain*, p. (li), 1913.

size of windows and upon the size of windows depends the character of the outside of the building (ix. 10).

5. CLIMATE AND COLOUR

The quality of the light as well as the quantity influences the value of colours



[H. B.]

FIG. 5a.—A MODERN GREEK BUILDING, SHOWING TONES PRODUCED BY COLOUR-WASHES ON A PLASTER SURFACE.

on buildings whether natural or applied (2). In some climates surfaces both in sun and shadow can be enlivened by applied colour—in others only surfaces in shadow. On Greek buildings colour-washes in ochres, reds, blues and greens were applied, and are applied to-day, to the bright surfaces. The colour-washes give variety of tone. This can be seen roughly in our illustration (Fig. 5a) of

11. 6. Theory and Elements of Architecture

a modern Greek building : the walls are in ochre, the structural members (antæ and lintels) are left white or ivory coloured, the frieze is a darker colour such as blue and the antefixæ or ends of tiles are red. All this is enhanced by the reflected light which can be seen beneath the cornice.

In certain snowy regions such as Russia and Scandinavia, where for a few hours in the winter day there is a brilliant diffused light from sun and snow combined, colour is found in the same strong tones upon the surfaces of roofs and cupolas. In these positions it is gay and telling, and enjoyed by the people. But in temperate climates characterised by mist and a general shallowness of light such as the British Isles, applied colour is not a tradition in building for a good reason. On the other hand, British architects have a series of lovely natural tones from the surfaces of materials like flints, red bricks, and coloured limestones and sandstones acted upon by the weather. The alternating wet and fine in our weather acts ceaselessly upon materials—disintegrating and toning the surface—in a way that has no parallel in dry climates. Even a marble such as that used in the Marble Arch in London soon loses its ivory quality and becomes a pearly matt surface. It is wise then in England to design a building that shows a matt surface to best advantage unless special materials are procurable. But the object of the architect is to design for brightness and he must not ignore new materials. The active enemy of the bright surface is smoke which turns rain-water into an acid and deposits layers of soot. In the industrial city this is a constant danger. Many fine Classic buildings built of grit-stone in the north of England have blackened and disappeared. When smoke is added to mist then architecture scarcely survives. Ingenuity in the design of city wall surfaces must go hand in hand with a progressive policy of smoke abatement. Designing for brightness under these climatic conditions is discussed in the second chapter on walls (v. 8 and 9).

But we must push a little further our discussion of the results on architecture of the English climate.

6. INFLUENCE ON TASTE OF THE TEMPERATE CLIMATE

Another tendency of the English climate and of its variations between wet and fine is to produce in the mind a confusion of critical standards in architecture. We have seen from first principles that a bright climate such as the mediterranean will produce states of mind and building shapes different from those produced by a northern climate (ii. 1). But in England the two climates exist in the same

region, sometimes alternating from week to week. This causes an alternation in essential moods having far-reaching effects. Which of us has not distinguished in himself a change of mood between the wet and fine day, between the indoor wet summer and the outdoor fine summer. The change is a change in mental outlook and in what we expect from life. The direct enjoyment of open-air shapes and colours in sunshine out-of-doors causes one set of values: the absence of this direct enjoyment, and the necessity to find compensations of different kinds under a roof causes another set. The distinction is fundamental in architecture, and we find that two opposite sets of preferences and critical standards correspond broadly to these two sets of values. In England the result of the dual climate has been to preserve them both unresolved in the same people—a preference by some for northern or “Gothic” shapes, a preference by others for mediterranean or “Classic” shapes.¹ We shall see in the chapters on roofs how the practical result in architecture of these two sets of preferences existing side by side has caused in the English history of building a frequent variation in the shape of the roof. The alternate rising and falling of the roof in English architecture (vi. 4) and (vii. 8), and other curious gyrations in design which we shall notice (ix. 7), are the symptoms of conflict and of a consequent instability in artistic forms. Partisans have tended to link up “the Gothic” with the practical and social side, with good construction, with happy craftsmanship, and to link up on the other hand “the Classic” with the contemplative or æsthetic side, with order and symmetry and with grand effects. We have seen that there is in the origin of shapes some reason in this (ii. 1). But we shall see also that the great Gothic builders intellectualised their shapes as marvellously as did the Greeks, and on the other hand that the Egyptians and Greeks were also masters of craftsmanship and, within self-imposed limits, masters of pure construction. In the study of architecture false simplifications are dangerous. In England we should recognise that on certain sunny days the well-proportioned Classic house looks admirable in our streets and the Gothic railway station looks lifeless and exotic: but that on other days the wet Classic portico looks the fool, and the only shapes that tell in the half light are those with a striking silhouette such as is given by high roofs, towers and spires. The two sets of values are side by side in our climate and in our character, and each act in turn, and in varying degrees, upon the designer. We shall see that there have been one or two schools of builders

¹ These mixed preferences are also due to the mixture of race in the English people, but the alternations of climate have tended to preserve the separate elements by reinforcing the primitive moods now of one element and now of another.

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at rare intervals, such as the seventeenth-century French Renaissance builders, who have been able successfully to fuse the two opposites by means of a consummate art (vii. 7) ; but it is by no means self-evident that they must be fused. The activities and aspirations that have produced both sets of values and shapes are still called forth by the enduring problems and conditions before men and women, and both are probably required in a deep and complex civilisation. The truth of both sets of values is likely to last as long at least as the climate conditions that helped to produce them. What is important is to avoid wasteful conflict between the two when the problem at issue is fundamentally an artistic one.

7. INFLUENCE OF BUILDING MATERIALS

The materials of the earth's surface provide the means of solving those essential problems set by climatic conditions. For every considerable building there is somewhere a quarry or a brickfield or a gap in a forest.

A glance at the map showing building materials (Fig. 6) suggests that men used first what came to hand and that the great schools of building coincide with various fine sources of material. Egypt and Mesopotamia have the best alluvial mud for supplying sun-dried bricks, but Egypt—unlike Mesopotamia—has also stones of every kind bounding the narrow stretch of alluvial mud (iii. 1 and iii. 5). Greece is itself a marble peninsula (iii. 2). Rome is planted on a spot where two of the most valuable materials coincide, namely, a material called *pozzolana*, giving, when mixed with lime, a natural hydraulic¹ cement and a fine river-bed deposit of limestone known as *travertine*. The fact of these equally valuable materials existing in the same locality caused an equal development of two techniques, the “concrete” and the “masonry,” which gave to the Romans their mastery in building construction (iii. 3). France has a series of geological formations supplying the finest limestone, and upon these formations the great Gothic cathedrals are grouped (iii. 7). In England the number and variety of geological outcrops have caused a wealth of original building types, which form a study by themselves (iii. 8). And where building stones are not easily available as in Holland, East Anglia, the Bourbonnaise district in France, or the valley of the Po in Lombardy, there the brick and *terra-cotta* styles have developed. In the same manner the characteristic wooden architecture is found in the great forest districts of Scandinavia, Switzerland, Germany, and Russia (ii. 9).

But once a school of building was established the builders would go great

¹ That is a cement that will “set” or harden under water.



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distances for precious or beautiful material. Originally all building stone was precious and was used to give durability, in sacred buildings, to clay or plant building forms, and these forms were at first imitated closely in the stone (iv. 5). Durability was considered equally with appearance. Hence there developed



FIG. 7.—EGYPTIAN MASONRY COLUMNS IMITATING BUNCHES OF PAPYRUS STEMS (KARNAK).

such forms as the masonry shaft used by the Egyptians¹ for their temples in imitation of posts made of bunches of papyrus stems (Fig. 7). Now we have seen that climatic conditions in Egypt favoured the architecture of the colonnade; but also there were in Egypt quarries having beds from which large stone shafts could

¹ Capart, J., *Egyptian Art*, 1923, Ch. viii., Forms in Architecture, p. 121.

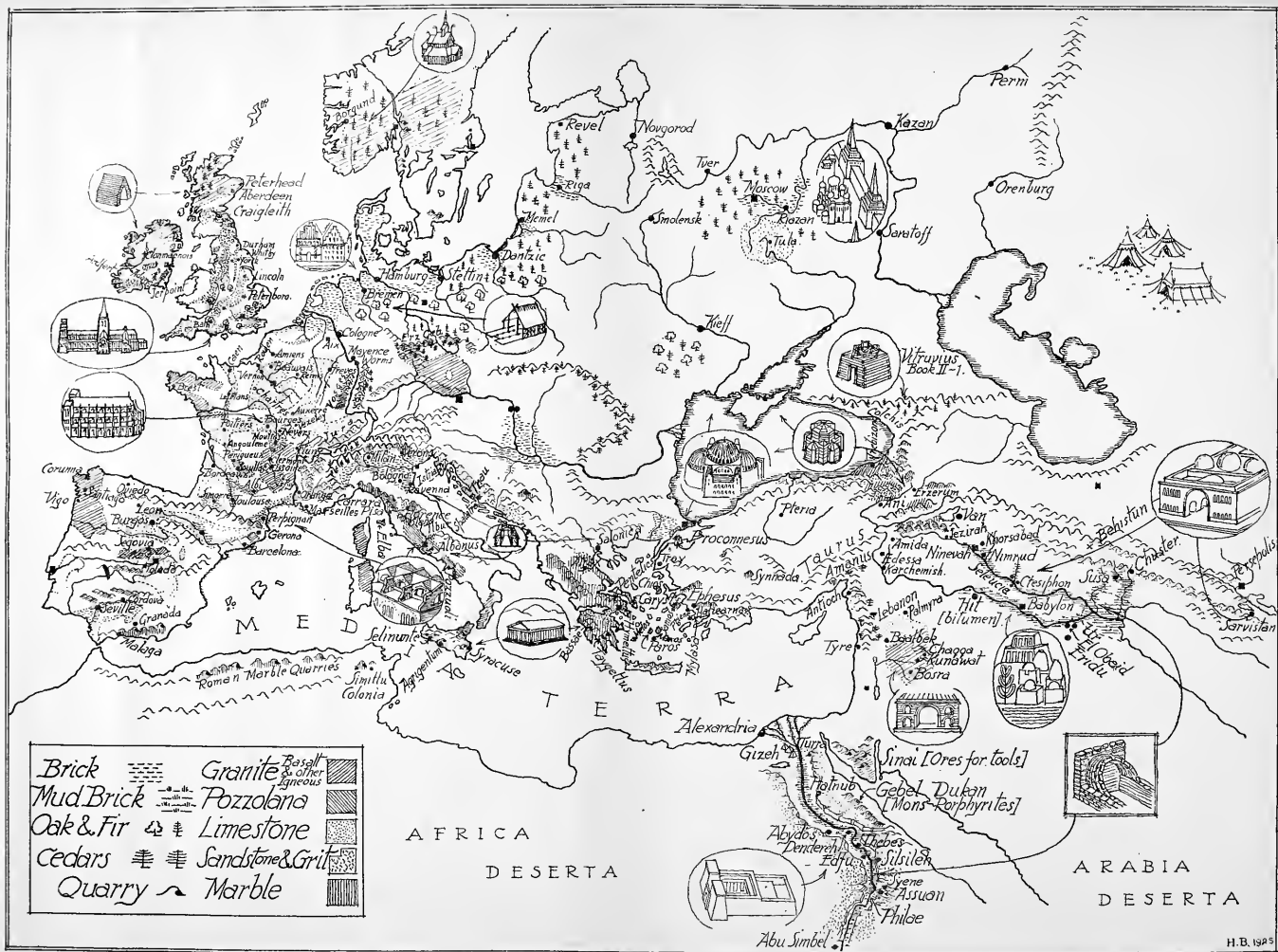


FIG. 6.—MAP OF BUILDING MATERIALS AND OF THE CHARACTERISTIC BUILDING FORMS OF EUROPE AND THE ANCIENT WORLD.

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¹ Capart, J., *Egyptian Art*, 1923, Ch. viii., Forms in Architecture, p. 121.

be cut all in one piece (iii. 1), and this fact helped to produce the characteristic architecture of the colonnade. It helped also to produce "monolithic" building.¹ In Mesopotamia stone was very scarce, and it was long thought by archæologists that columns were not used by the Babylonians.² But beyond Mesopotamia in the mountains of Persia the long "banks"³ of limestone were able to give shafts having sections 18 to 20 feet in length. As a result the very tall column is found giving a character of its own to Persian architecture and reacting (through the Persian conquests) on Ionia and on the Ionic order, and thus contributing to the distinction between the Ionic monolithic and the Doric shaft built up in short drums.

The size of quarry banks and the length of stones able to be extracted from them has always influenced design; where large stones were procurable men have usually been willing to expend the great labour necessary to extract and transport them. The marble lintels available for spanning a distance of twelve feet and more, sufficient for the passage of a chariot, made it possible for the Greek builders to ignore the arch in large buildings.⁴ Conversely where only small sized stones or short length timbers were to be had inventive builders such as the Sassanid Persians, and the Armenians, were driven to the vault and dome in order to span large areas.

The easy transport of materials was a vital consideration; it was therefore largely along waterways. We find that the great permanent sources of building stone—quarries two thousand years old and still in use—are generally near rivers or near the sea. From such quarries in Egypt, Greece, and the African coast, stones have been carried by water to Rome, Constantinople, Venice, London, and the material has successively influenced the buildings.

The influence of the strength of joints is a vital influence upon design. This also was a matter of geology and the materials available in any district. The degree of strength of the joint conditioned the degree of homogeneity of the wall or vault. When the strength of the joint approached the strength of

¹ "Monolith" means single-stone. Monolithic building means building in such a way that the completed structure shall look as much like a single unjointed whole as possible (iv. 5). The opposite of this is "many-stone" building, in which joints are emphasised (v. 5) by means of "rustication" or marginal channelling.

² There is now evidence that the column in Mesopotamia, attached and unattached, was known and used from Sumerian times onward. See C. L. Woolley. Excavations at Ur. *Antiquaries Journ.*, Jan. 1925. B.M. reprint, p. 7.

³ Banks or beds, see note, page 66.

⁴ The lintel stones of Pentelic marble over the central opening in the Propylæa at Athens are 18 ft. long and span 12 ft. 6 ins. between supports. (Penrose, plate 28, Ch. x.)

the material then the moulded or concrete structure was likely sooner or later to develop with its appropriate curved forms of vault and dome. Hence the eastern mud dome and hence, supremely, the pozzolan construction of the Romans (iii. 3).

Where lime existed, or could be procured by grinding, the lime mortar of moderate strength produced a variety of forms but lime mortar conditions were unable to give the homogeneousness of the pozzolan joint and in consequence Gothic vaulting required the scaffolding of flying buttresses. Early joints were roughly of three kinds—lime, asphalt, or metal. This is illustrated by a sentence from Procopius describing the great piers of St Sophia at Constantinople: "They are fastened together not with lime (titanos), called "unslaked" (asbestos), not with asphaltum, the boast of Semiramis at Babylon, nor anything of the kind, but with lead, which poured into the interstices, has sunk into the joints of the stones, and binds them together; this is how they are built." ¹

The technique of Attic temple building of the Periclean period was not a mortar joint and masonry technique but a marble joinery with metal cramps. This was the result in monolithic building of an enormous skill in marble grinding (p. 117). The Cretans had a clay cement which enabled them to roof their buildings satisfactorily to a very slight fall (p. 198) and gave considerable strength to their walls. The bitumen, "boast of Semiramis at Babylon," likewise enabled the citizens of the various Mesopotamian countries to joint their bricks satisfactorily in a water-logged country and defend themselves against a diluvial rainfall (iii. 5). The twentieth century is again an era of the homogeneous joint. Portland cement can provide a joint as strong as any ordinary masonry or clay material. Economic conditions modified the application of Portland cement, but there is no doubt that the ordinary mortar joint to-day could be twice as large as is generally the case and that in a strong Portland cement mortar the ordinary bonding of bricks (p. 168) is unnecessary.

8. STONES AND STYLES

The texture of a stone is a powerful factor in defining a masonry style. We have already seen (ii. 3) that a building is noticeable in proportion to the amount of light reflected at its surface. The colour, the smoothness, and the hardness of a stone contribute to its light reflecting qualities, and upon these qualities depend the value of mouldings and ornament and the beauty of sustained lines

¹ Procopius, C., *De Edificiis*, 1662. (Quoted in Lethaby and Swainson's *Sancta Sophia*, 1894, Ch. ii., p. 27.)

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or large unbroken areas. The Greek pentelic marble had an ivory-white translucent surface and came to a sharp edge or *arris*. This bright and clear surface was tempting to mould, inscribe, and colour, but the long sharp edges given by the unbroken lines of a Greek building were liable to produce a rigid "cast-iron" appearance. Hence one reason among others for the phenomenon in Greek architecture known as the "optical corrections." The exactness of the material helped the Greeks to develop a wonderful series of slight curves and inclinations designed both to correct the hardness of line due to the material and compensate for illusions of shape due to the human eye. In countries where the best stones do not come to so sharp an *arris* the delicacy and subtlety of an open-air marble style thus refined can be realised only approximately. But other fine stones have produced fine styles. The limestone of Caen and of the Paris basin is the material that first produced the intricate strength of the French Gothic. These stones are soft enough to allow of delicate carving and bright enough to show off narrow under-cut mouldings.¹ Grit-stones and granites reflect the light less, and Gothic mouldings in these materials require to be broader and shallower:² granite Gothic is specially hard and angular.

The hard, but pleasantly toned, grit-stone of Craigleith, warm brown in colour, weathering sufficiently brightly to be seen, produced a singularly sharp and refined Classic style in the "new town" of Edinburgh at the end of the eighteenth century, which developed later into a Greek "revival" owing largely to the material. The characteristic blacks and whites of London stone buildings are due to the peculiar weathering properties of Portland. The Classic architecture of Dublin differs again from that of the other two capitals by reason of the heavy grey granite quarried in long blocks from Killiney Hill.

9. *TIMBER STYLES*

The influence of the nature of timber on design has been considerable in the history of structure. The carpenter makes himself felt in many ways. Where timber is available but not abundant, as in the Ægean civilisations, his posts and lintels are liable to be transposed into masonry, and we shall see in Greece (p. 116)

¹ Caen stone when new has a light reflecting coefficient of 68 per cent. An ordinary "buff stone" colour reflects 47 per cent. (2)

² In Gothic Architecture the degree of hardness and reflecting power of the material used and its influence on the character of the design is noticeable;—compare and contrast the well-known cathedrals of Salisbury (Jurassic limestone from the vale of Wardour) with Cologne (a sandstone from the Black Forest) and Milan (marble from the Monte Candido, near Lake Maggiore).

that it was an elementary kind of carpentry that was thus transposed and that came to be developed into the "Doric Order." The great sources of timber in the ancient world were Lebanon and Amanus in Syria (Fig. 6) which were laid under contribution by Egyptian, Babylonian, Assyrian, and by all the great dynasties of the ancient world (Fig. 88*a*). We shall see that as these famous cedar forests were cut down the eastern dome and vault spread westward (iii. 6).

In the same way it is probable that when the timber supplies of the ancient kingdom of Armenia were cut off the early Christian church builders in that country were forced to build their walls and bridge the angles of their ceilings in stone instead of timber (iii. 6). The method of roofing in timber by bridging the angles follows naturally upon the kind of timber construction known as "block house" or "log house." This is described by Vitruvius as the building practice of the Colchi who inhabited a region on the shores of the Black Sea to the north and west of the old kingdom of Armenia (Fig. 6). "The woods of the Colchi, in Pontus, furnish such abundance of timber that they build in the following manner. Two trees are laid level on the earth, right and left, at such a distance from each other as will suit the length of the trees which are to cross and connect them. On the extreme ends of these two trees are laid two other trees transversely: the space which the house will enclose is thus marked out. The four sides being thus set out towers are raised, whose walls consist of trees laid horizontally but kept perpendicularly over each other, the alternate layers yoking the angles. The level interstices which the thickness of the trees alternately leave, is filled in with chips and mud. On a similar principle they form their roofs except that gradually reducing the length of the trees which traverse from angle to angle they assume a pyramidal form." (3) This pyramid over a square plan transposed into stone can be traced in the Greek masonry tomb at Mylassa in Caria; it was probably a general building practice in eastern lands before the deforestation period and contributed, among other factors, to the development of the dome over a square plan.

Block-house construction requires abundance of straight timber and generally limits the plan to the length of trees available. It has spread in Europe "westward to Switzerland and northwards to Scandinavia. The European settlers took it with them to the new and well-timbered continent of America and the Russians have carried it across Asia as far as the Pacific Ocean. It has therefore girdled the world, and doing so it has followed the forest belt of coniferous trees of the north temperate zone." (4)

The Swiss chalet owes its character to this type of construction: the roof

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is generally at a low pitch over a square plan and consists, like the walls, of straight logs placed horizontally but projecting out as far as possible beyond the gables in order to give protection beneath. The bark is left upon the logs and the timbers of the roof are protected with heavy stone slates. The snow, owing to the low pitch, remains on the roof all the winter and helps to preserve warmth within. (5) In Scandinavia two kinds of early timber building can be distinguished—one akin to the block house, but more developed, upon which the snow rests, and the other having a high-pitched roof designed to throw off the snow. In our illustration of the first kind (Fig. 8) it can be seen how the projection of

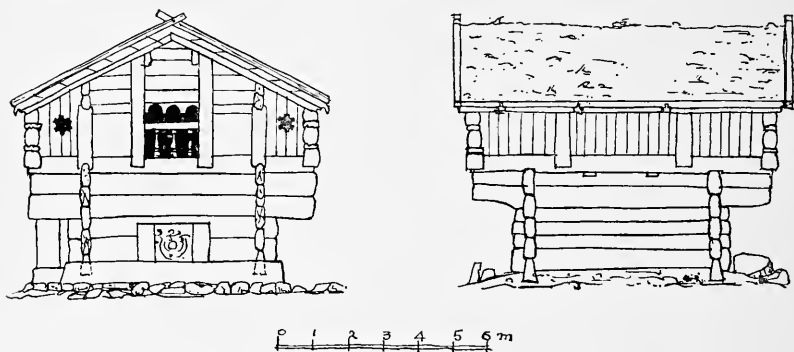


FIG. 8.—NORWEGIAN STORE HOUSE AT OSE. (*After Dietrichsen and Munthe.*)

an upper floor can come about as easily as the projection of the roof if timbers of sufficient length are available. The second type is much more highly developed and is seen at its best in the Norwegian timber churches of the twelfth century. (6) These churches are in many ways masterpieces of construction and show the influence of the shipbuilder. Thwart, keel, and gusset are all visible. At Borgund¹ (Fig. 9) five roof trusses resembling scissors trusses (vi. 3) are strengthened by gussets and come down on to stout plates like gunwales which are tied by two tie-beams resembling thwarts. The whole is supported on timber masts stiffened at half their height by cross struts forming a kind of lattice-girder and again near the top by the wood roofing of the aisles. The plan, due directly to the construction, is a series of rectangles plus an apse (Fig. 10),

¹ Other examples are found at Gol, Stedje, Hitterdal, Fortun.

the dividing walls and the floor playing a necessary part in the box-like structure. The buildings are boxes supporting inverted boats. In these churches many

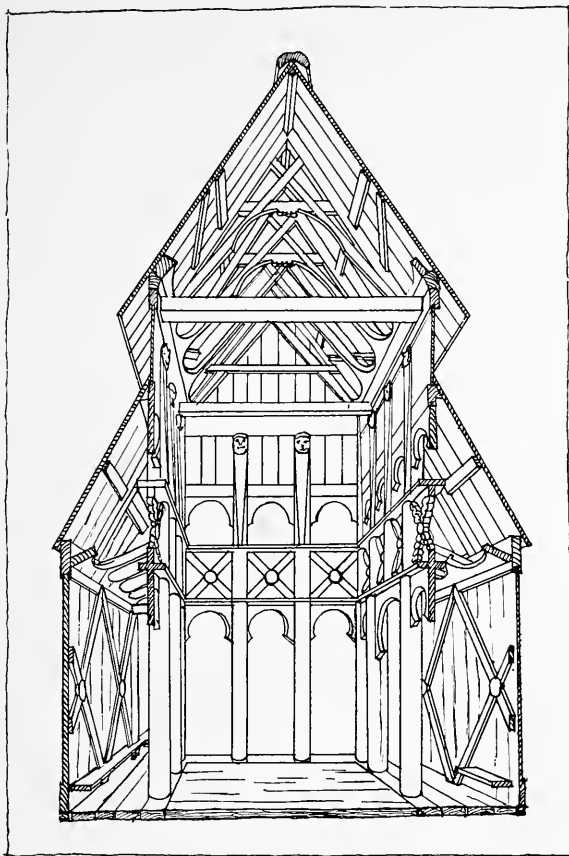


FIG. 9.—NORWEGIAN TIMBER CHURCH AT BORGUND.
(After Dietrichsen and Munthe.)

motives are combined. The apse and the lofty pointed character of the interior foreshadow French Gothic; externally (Fig. 11) Armenian and Russian shapes

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are suggested as well as the distinctively Norse; a pagoda-like effect is produced by the dragons which terminate the roof ridge, and the interlacing carvings resemble early Celtic. The aisle walls are built in upright timbers and at the east end these upright timbers are easily formed into an apse. Upright timber construction is found in England at Greenstead at the little church near Ongar in Essex. Walls are formed of half trunks of oak trees set upright, with the split faces inwards and a three-quarter trunk on the angle (Fig. 13). The upper end of each half

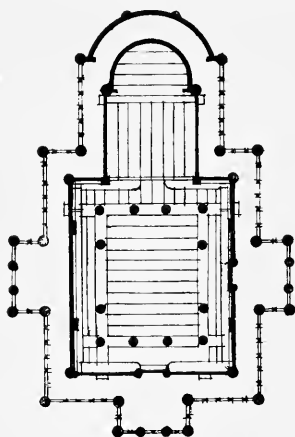


FIG. 10.—PLAN OF BORGUND.
(After Dietrichsen and Munthe.)

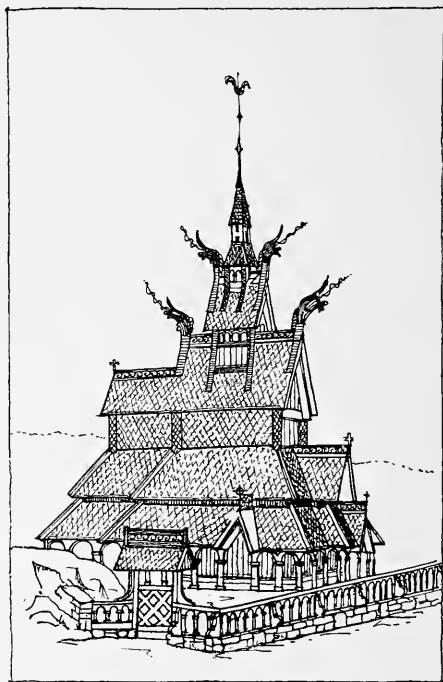


FIG. 11.—TIMBER CHURCH AT FORTUN.
(After Dietrichsen and Munthe.)

trunk originally was roughly tenoned into a plate and the lower end into a sill set upon the ground. (4) A view of Greenstead church is given in Fig. 12. This method of walling was similar to the stockaded structure of secular buildings in Anglo-Saxon and Norman times.¹ It is surprising, therefore, that the

¹ Stockaded forts are illustrated in the Bayeux tapestries.

apsidal east-end—possible with stockaded structure but impossible with “block house”—should have been rare in England and that on the contrary the square east-end should have been the rule. But England was always a hard-wood country and fir and pine had always to be imported. To this day neither fir nor pine are recognised as timber trees by the common law of England. Our timber construction tended therefore to rectangular oak framings. But fir was required for the masts of ships and there is evidence of the importation of boards from the north of Europe as early as the thirteenth century. (7) The importation of fir to England became considerable in Renaissance times and there are instances of Elizabethan panelling in soft wood. Pine existed in the highlands of Scotland but it was not marketable; the lowlands were always liable to deforestation.



FIG. 12.—GREENSTEAD CHURCH, ESSEX.

[H. B.]

The difference between the general growth of English and French oak of the same species¹ produced differences in the characteristic timber construction of the two countries. The English oak, common on park land and open woodland, has large irregular limbs and, skilfully used by carpenters, has produced the well-known braces, bracquets, and curved members of the English roof and half-timber house. In France there is generally a straighter oak (8), and French half-timber work has on the whole fewer curved pieces than the English. More important still this difference is reflected in the design of large roof trusses in the two countries (vi. 10). The reason of this difference is due to the French practice of deliberately planting oaks close together in forest land, a practice which has never been followed to the same extent in England. When oak trees grow close together a longer main stem is the natural result. In England the woods



FIG. 13.—PLAN OF NAVE TIMBERS, GREENSTEAD CHURCH.

¹ The common oak includes two species, the pedunculate and the sessile; of these the pedunculate common in the south of England has the more curved and irregular branches, the sessile, common in the north, the more defined main stem and branches slightly straighter.

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were more open and forest land more resembled modern park land. The two kinds of timber produced by the two kinds of growth are shown in Fig. 14. The French development of the thin tie-beam and light truss (vi. 10) was the result of the use of comparatively thin straight *trunks*. The English carpenters on the other hand made great use of massive *branches*, as for instance in the construction of the arch-brace and hammer beam.

The English oak and the English elm were distributed over the whole country



English or Park-grown Oak.

[H. B.]



French or Forest-grown Oak.

[H. B.]

FIG. 14.—COMPARISON OF THE ENGLISH AND FRENCH-GROWN OAK.

upon the heavy clays. Thus the bricks and timbers are often found together. Oak forests were preserved for the Navy and it is probable that the King's timber supply was used equally for the Navy and for the King's buildings. Thus the New Forest supplied the southern ports, Essex supplied the Thames shipyards, the Forest of Dean supplied Bristol. Timber styles roughly correspond with these forest supplies. The English carpenters in the Middle Ages became so skilful in using the English oak with the special characteristics we have described that open timber roofs spanning larger dimensions than the stone vault were frequent. The English Plantagenet and Tudor Hall, the English Perpendicular

parish church with its unimpeded floor space, its ample windows and fine timber roof, is the direct product of the interaction of the English forester, carpenter, and mason.

Another type of wooden structure fundamental to architecture which should be considered at this point is the "basilican" farmhouse type, three aisles in width, and built in bays of standard dimensions.

This type can be, as to its main timbers, either of fir or oak and is of the nature of panel construction rather than block-house. Panels of wattle and daub or clay blocks filled the interstices between posts (vertical) and transoms (horizontal) (Fig. 14a). It is shown on the map of building materials (Fig. 6) as a form characteristic of Germany and her forests,¹ but traces of the type have been found in

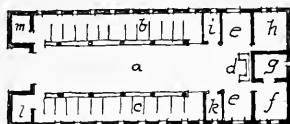


FIG. 14a.—PLAN OF BASILICAN FARM HOUSE.

England in districts remote from towns, at Spoonley Wood, Ickleton, and Mansfield Woodhouse.² To this day the type survives in Friesland and Saxony. This building is worth special study at the outset of any narrative of architecture. It is the first farmhouse—the home of the stock farmer in whatever climate and cannot be confined to northern conditions only.³ But its plan reveals much more than this. With its nave and aisles, its transepts and its hearth, we can read in it the Greek temple, the Roman basilica of justice, the Roman domus and the Christian church. If we translate the domestic "hearth" into the sacrificial hearth or altar uniting elements of sacrifice, cookery and warmth, and, as we have seen (ii. 2) the element also of compensation for lack of sunlight, we shall find in the plan the seed of many future developments.

From the point of view of construction it is equally important. It is designed in "bays" of standard dimension arising from convenient timber lengths which became a unit measurement (in England a "bay" was about 16 feet). This meant that it could be extended any length as desired. In the twentieth century we have returned in steel structures to building by bays but have not standardized the dimension. A standard bay-unit enables the design of steel-frame structures to be simplified, and city building rendered more uniform. The comparison of steel-frame carpentry with timber carpentry is not an archæo-

¹ For the description by Meitzen of the details of the plan, see *Appendix, Note 2*.

² Ward, J., *Romano-British Buildings and Earthworks*, 1911, Ch. vii.

³ "Galen describes peasants' houses, which similarly combined dwelling with farm offices under a common roof, in Asia Minor, in the second century of our era." (Ward, *op. cit.*, p. 181.)

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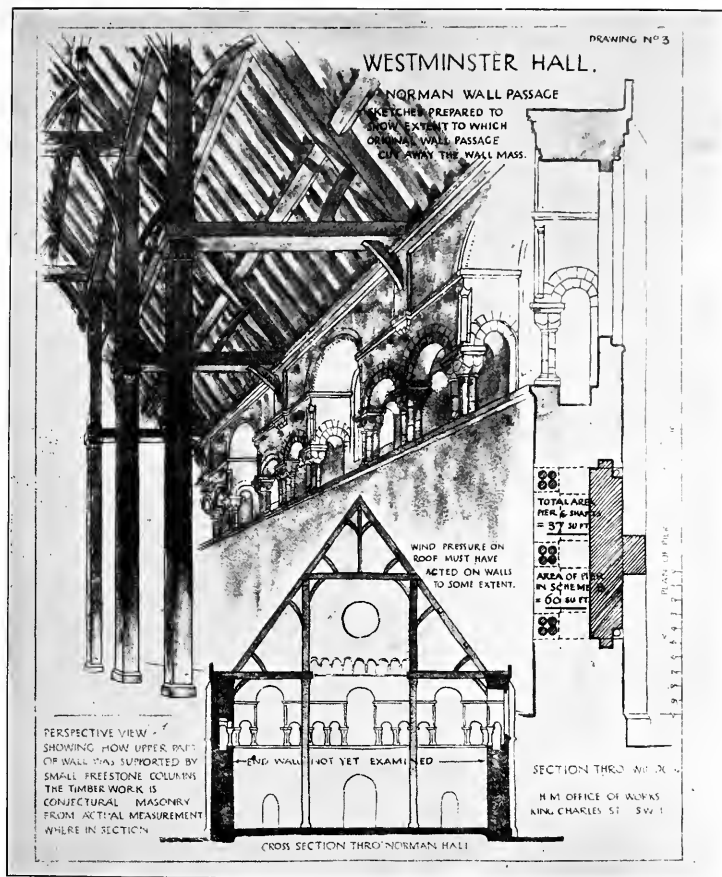
logical exercise but directly useful. In the same way the wooden posts supporting the roof of the Saxon house can be traced as a wooden structural system having its



[By permission of the York Corporation.]

FIG. 14*b*.—YORK. TIMBER PIERS IN GUILDHALL.

own canons and producing its own effects. The timber pier, consisting often of the whole tree, can be seen in England in the Guild Hall at York (Fig. 14*b*). West-



[By permission of the London Society.]

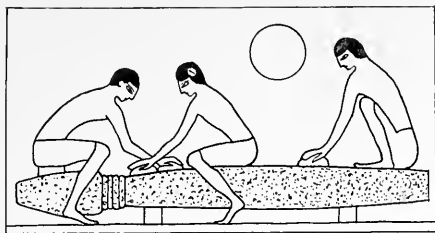
FIG. 14c.—WESTMINSTER PALACE. CONJECTURAL RESTORATION OF THE NORMAN HALL OF KING WILLIAM RUFUS BY H.M. OFFICE OF WORKS.

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minster Hall roof was the product of the English-grown oak and of the English carpenters' art (vi. 10). But the famous hammer-beam roof at Westminster (Fig. 104) may also have an earlier element in it. The conjectural restoration by the Office of Works shows a three-aisle building, the roof of which was supported upon beams resting upon timber piers which take up position on plan now surviving in the hammer posts (Fig. 146).

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- (5) TROUP, F. W. Influence of Materials on Design in Woodwork, essay from "The Arts connected with Building," 1909. Swiss House, p. 66.
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THE MONOLITH.

Chapter III

BUILDING STONES

1. STONES OF EGYPT

THE architecture of Egypt is part and parcel of its geology. (1) Timber was scarce—the palm is not a timber tree—but for masonry purposes the Egyptians had the finest and most varied material. The Nile, flowing northwards, has worn a narrow gorge through the sandstone of the Libyan desert and at a point in its course some seven hundred miles from the sea it encounters a ridge of granite, the last of a series, through which the great river has scarcely worn a passage. This ridge is known as the “first cataract” and is part of a granite outcrop on the east side of the river. Here are the red granite quarries of Syene.¹ Here also is the ancient market of Suan or Assuan to which came the traders from the Sudan. The original Egypt of ancient times lay between the first cataract and the sea and consisted of this seven hundred miles of river valley. Below Assuan the Nubian sandstone continues for some seventy miles down stream and at Silsileh occur the chief sandstone quarries, but below this the valley begins to widen out owing to the geological change from the sandstone to the softer limestone table-land of the northern desert. Here begin a series of great temples—first Edfu, then Luxor, Medinet Abu, Karnak (these three in the neighbourhood of Thebes) and Denderah.

Below Edfu the Nile valley between bluffs widens out to a span of twenty or thirty miles and henceforward the rocks are predominantly of the Eocene limestone. These bluffs with their bold rectangular markings are physical features

¹ Syene has given its name to “syenite,” a granite practically free from quartz : but the Egyptian rock quarried at Syene is properly a hornblende granite.

III. I. Theory and Elements of Architecture

in the landscape which cannot be ignored. They are the dominating background in front of which the buildings must stand. They account æsthetically both for the large rectangular and the pointed obelisk shapes in Egyptian architecture. The former, if sufficiently large and emphatic, will harmonise with the landscape, the latter will contrast (Fig. 15). In both cases a great scale and a grand manner are necessary, for no other treatment will tell.¹

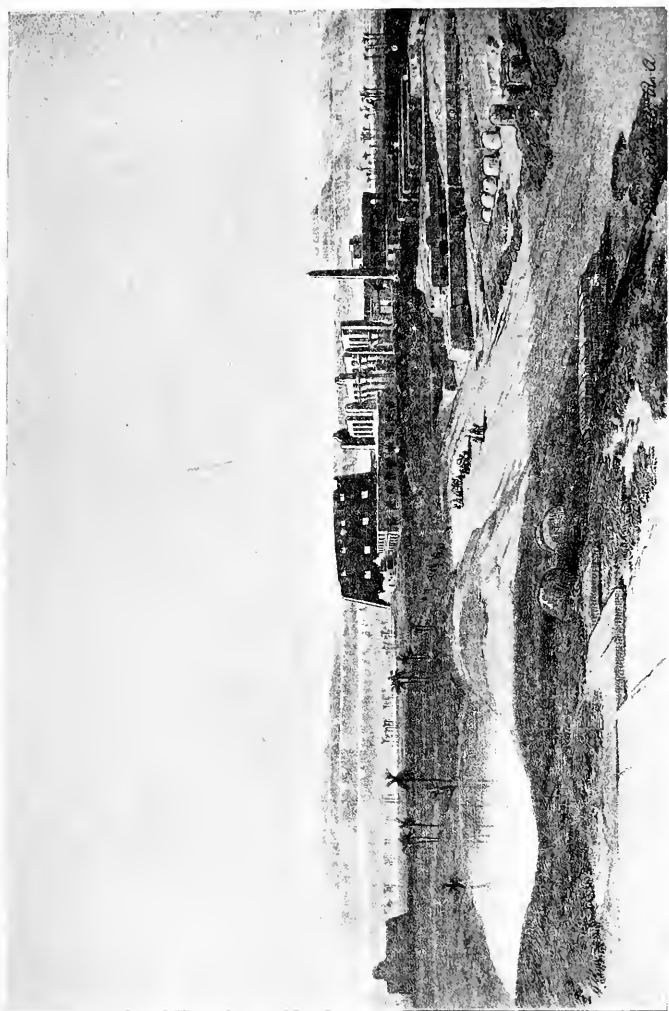
The great limestone² quarries that supplied the Gizeh pyramids are found opposite them, at and near Turra. From these quarries 2,300,000 blocks, each weighing on an average $2\frac{1}{2}$ tons, were supplied for Khufu's pyramid alone; they were ferried across the river when the flats were flooded and taken to the foot of the great ramp which led up to the pyramids. (2) In the eastern desert there are fine beds of alabaster quarried at Hatnub near el Amarna and elsewhere. (3) Farther east a series of hills along the shores of the Red Sea supplied hard stones (4) such as black granites, diorites, and porphyries: ³ one of these hills—Gebel Dukan—was probably the Mons Porphyrites, well known at a later period to Roman and Byzantine builders. The stones from these hills were transported through the Nile canal connecting the Nile and the Red Sea, dug by the ancient Egyptians and already in use by the time of the Middle Kingdom. In the region to the south-east of the delta there are isolated outcrops of the green basalt, and Sinai peninsula yielded the copper from which the Egyptians forged their tools (*see* Fig. 6).

With this bird's-eye view before us it is easy to see a reason why the pyramids in the north were built of limestone and the great temples on the island of Philae, in the south, are in Nubian sandstone largely from an open quarry near Kertassi. (3) But there was easy transport of stone up and down the river, and granite blocks thirty feet long were conveyed in boats down stream from the first cataract. Frequently several types of stone are found in one building. Also the Egyptians used the same stone indiscriminately for statues and sacred buildings and seem to have regarded both processes equally as a kind of sculpture. The colossal statues in front of the rock-cut temple of Abu Simbel, south of the cataract, are in Nubian sandstone and so are the sphinxes in the great avenue at Thebes. The

¹ But the foundations of these necessarily large buildings could be nothing but the alluvial clay which formed the floor of the valley and which, though tough, was inundated every year by the river and then again contracted by the heat of the sun. Hence the necessity for the wide base of Egyptian walls and the development of the sloped or pyramidal shape which tends to distribute weight (iv. 7).

² The earliest masonry building in Egypt, a second dynasty tomb, is of limestone and occurs at Abydos. (Petrie's *Royal Tombs*, vol. ii. 57, 5.)

³ "It seems not improbable that all these hard stones were found in the same region, the Eastern desert, and that they were all worked by one school." (4)



[From Roberts' "Holy Land and Egypt,"

FIG. 15.—EGYPT. PHYSICAL FEATURES AND BUILDING SHAPES.

III. 2. Theory and Elements of Architecture

red granite of Syene provided near at hand the famous obelisks of Assuan. An objection to the Nubian sandstone is that it stands less well the alternations of wet and dry due to the annual inundation.¹ The Egyptians do not seem to have used bitumen for buildings in the manner of the Mesopotamian builders (though bitumen was used for mummification), but at Denderah we find the lower courses of columns in red granite and the superstructure in red sandstone, a precaution which may have been designed to resist the action of water as well as to give extra strength.

Many of the quarries were far from the river and enormous labour was involved in transport. Armies of labour consisting of as much as two thousand men were sent into the desert to transport material. In many of the great quarries to this day there still remain the blocks and obelisks, partially excavated, that were intended for the Pharaohs. In one of these quarries an interesting inscription records the first use of the "ramp," or inclined way, by a clerk of the works named Meri in the year 19 of the reign of Amenemhet III. (about 3300 B.C.).² There is no mystery about the manipulation of the great blocks from these quarries. The ramp, the roller, the lever, and the highly skilled direction of labour are the factors successfully employed to-day by archæologists in the moving of the same blocks and restoring the same buildings. The mystery really lies in the ancient method of case-hardening copper. The hardest basalts and porphyries were cut and carved by copper tools, though iron was not unknown. Band saws and tubular drills were used in the quarries and worked in sand or emery dust. Also there is evidence that small blocks of emery were fixed as teeth into copper blades. (4)

2. GREEK LIMESTONES AND MARBLES (5)

Greece and its islands consist chiefly of limestones, said to belong to the Cretaceous system,³ converted over large areas into marbles and other metamorphic rocks. Mountains are caused geologically by a folding of the strata due to earth pressures and the resulting high temperatures are often the cause

¹ The temple of Philae in sandstone is now partially submerged annually by the operation of the Assuan dam and the damage done to the material by the alternations of wet and dry is considerable.

² Couyat, J., and P. Montet, *Inscriptions Hiéroglyphiques et Hiératique du Ouadi Hammamat*, Cairo, 1912. Some of the inscriptions are summarised by Capart. (3)

³ The marbles are shown chiefly as Cretaceous on the Carte Géologique Internationale de l'Europe; the Attic marbles have also been referred to the Tertiary period. (6) Cretaceous is a Latin term meaning chalky and is connected with *Creta*, the Latin name for Crete, whence came a white rock.



K C B

FIG. 16.—A SICILIAN LANDSCAPE.

III. 2. Theory and Elements of Architecture

of the fusing of limestones into marbles. This was probably the case in Greece, and we shall see that this process caused the considerable marble horizons of the Carrara district in Italy (iii. 4). Marble and its qualities has largely contributed to the delicate strength of Classic forms (iv. 11). Also the actual contours of the Greek or Sicilian landscape formed often of limestone or marble peaks boldly sculptured by natural agencies, and in ancient times wooded on their lower slopes, must be considered in any study of Classical architecture. The landscape has a style, a formal beauty of its own (Fig. 16) which seems to enjoin upon a building certain qualities of strength and refinement.

Round the plain of Argos the hills provided a hard compact limestone in inclined beds with many cleavages. This stone, owing to the strata, could be

extracted in large irregular blocks which a little dressing could render polygonal. Hence occurs the large irregular masonry of Tiryns and Mycene characteristic of the earlier Ægean civilisations. The same inclined beds in the neighbourhood of Athens produced the large polygonal masonry of the "Pelagic" wall on the acropolis, and in addition a smaller polygonal masonry which remained a constant building tradition. At Mycene the part of the hill within which the great bee-hive tomb known as the "Treasury of Atreus" was hewn, is formed of a conglomerate, and the same stone in regular "squared" courses was used for facing and retaining the tomb and entrance passage. This conglomerate was also used for sills and lintels in the large gateways at Tiryns and Mycene, but



[H. B.]

FIG. 16a.—MYCENE. LION GATE, LINTEL OF CONGLOMERATE STONE.

owing to its geological structure is not at all suited to take a bending stress, and we find as a result that the lintels are relieved by the corbelling inward of courses above it, leaving the triangular space characteristic of both early and late masonry

in Greece. Compare the Lion Gate at Mycenæ (Fig. 16*a*) with the Messenia Gate (headpiece to Chap. V.), and with the example at Iassus (*c* in Fig. 59).

But the stone of greatest importance in Greece is the Poros stone. This is a rough, shelly limestone (7) found in the deposits of Tertiary age¹ which extend along the west and north of the Peloponnesos and across the isthmus to Piræus—a belt shown dotted on the map (Fig. 6). The name of this stone both in Greek and English denotes its nature—it is rough and full of cavities (Fig. 16*b*) and gives an excellent key to plaster. We shall see (iv. 11) that the persistence in Greece of the monolithic or jointless tradition superimposed upon and concealing a masonry is due (among other factors) to the obvious key for plaster given by Poros stone. Plaster was had in all localities by burning limestone, and plaster on mud-brick was the earliest and is still the commonest of Greek wall materials. The mud-brick and timber temple, plastered and colour-washed, translated into Poros stone for the sake of durability, was not to change its bright, jointless character. Hence we find a number of



[H. B.]

FIG. 16*b*.—RUBBLE WALL IN POROS STONE.

Greek temples such as those at Selinus in Sicily, at Aegina, and Olympia, in limestone carefully plastered over. But in Pentelic marble the Hellenic Greeks had a material for jointless building finer than any in the world. Its surface was smooth and bright and its joints could be ground to an invisible fineness. The rock forming the acropolis of Athens, and the neighbouring hills consists of a mass of red and grey marbles, cipollinos and green schists; but the Hellenic builders ignored the coloured rocks for the sake of the underlying ivory-white of Mount Pentelicus (a few miles north of Athens). This was because they desired a clear bright surface that would take an even finer finish than the traditional plaster upon limestone. It was part of their monolithic tradition (iv. 11). Pentelic marble (Fig. 16*c*) is almost pure

¹ This Tertiary belt also provides a little sandstone in river valleys as at Olympia where a compact fine-grained sandstone, from the bed of the Alpheios, is found in buildings of every period used for bases.

III. 2. Theory and Elements of Architecture

carbonate of lime, and when newly broken shows a glistening white fracture.¹ The Periclean Greek deliberately used the finest sculptor's material for the resources of architecture. The full aims of their architects can still be partly read in the Propylaea. The grey and red marble of the rock itself, emerging from the grass and rock-plants, carried first a bastion wall of honey-coloured Poros stone in even courses having the finest joints. This wall was completed by a faint string and forms a transition between the rock and the Pentelic marble of the Propylaea which crowns it. The marble gave a surface which was tempting to inscribe with ornament and pick out with colours; here and there within the porticoes were strings of black Eleusinian marble (Fig. 16c). The colour was concentrated on the entablature and the roof lines must have showed the usual red-stained acroteria, whether of marble or terra-cotta. From the foot of the precipitous rock the whole was backed by the blue field of the sky.

The colours used were probably the yellow ochre and the red earths of the Attic soil seen to-day on the commonest Greek buildings—and in addition probably the green chalk from Smyrna mentioned by Vitruvius²—and possibly copper oxides.

The Pentelic marble by its sharpness of edge and line made more effective the slight curves and adjustments which give an unsurpassed delicacy to large Greek shapes. Finally it was the material not only precious but most durable: the Greeks built consciously for the sake of posterity as well as to please themselves.

The Greek mountain and island quarries are famous in history. The most famous—that at Mount Pentelicus—is worked to this day and there still exists the ancient slideway cut by the Greeks, and paved with marble, in which the posts were fixed for lowering the blocks by means of ropes. The vein of white marble goes far into the mountain producing a huge cave. (8)

The Parthenon, Theseion, Propylaea, Erectheion and the temple of Jupiter Olympius, are built of Pentelicon marble. The metope panels of the Theseion are in white marble from the island of Paros. Naxos, Samos, and other islands of the Cyclades,³ also provided white marble.

In Asiatic Greece white marble from the Lydian and Carian quarries probably supplied the temples of Ephesus.⁴

¹ The very thin reddish coat of "rust" that forms upon it in places after exposure to the weather can easily be scraped off with a penknife and reveals the pure white underneath.

² Vitruvius, vii. 7.

³ For the geology of the Cyclades see Homolle and Holleaux—*Exploration Archéologique de Delos*, Part I, French School at Athens, 1911.

⁴ Wood's *Discoveries at Ephesus*, 1877, p. 278.



[H. B.]

FIG. 166.—PENTELIC MARBLE. WALL AND WINDOW OF THE PINAKOTHEKA
IN THE PROPYLAEA AT ATHENS.

III. 3. Theory and Elements of Architecture

At Mount Pentelicus the beds of white were overlaid with fine red and green cipollino, which, ignored by the Hellenic Greeks, were quarried greedily by the Romans at a later date. Cipollino (meaning onion-figured) was cut across the bed and then gave the wave markings which were, and are still, considered highly ornamental. The Romans explored every hill for coloured marbles. A green cipollino was had from a quarry on Mount Carystus in Euboea; the large monolith columns of the temple of Antoninus and Faustina at Rome are said to have been cut from this mountain. Verde antico—a deep-green marble—was quarried on the plains of Thessaly near Atrax.

Grey marble and white marble was obtained from Mount Hymettus; ¹ green porphyry from Mount Taygetus. From the quarries in Laconia came black marble and from the island of Chios came the famous "Porta Santa" marble, ² whence later was cut the monoliths of St Peter and St Sebastian at Rome. (8) The island of Melos had supplied obsidian from the earliest times.

Thus Greece provided two kinds of material—a statuary marble of the finest quality for the Greek of the Hellenic period and later the most luxurious colours and textures for the Hellenistic and Roman world.

3. THE EQUIPMENT OF ITALY

The unique position of Rome in the history of structure is due to the wealth of her building materials. The agencies of fire and water had as it were prepared for her all the geological gifts. The greatest of these was undoubtedly pozzolana (*pulvis puteolanis*), a volcanic earth which when mixed with lime forms strong hydraulic cement. Pozzolana in its pure state is really a very finely-ground active silica and when used as an ingredient in a cement mixture gives also fire-resisting properties. ³ Pozzolana cement made possible the great vault and dome con-

¹ The white Ionic columns of the nave of St Maggiore in Rome are said to be from Mt. Hymettus.

² *Porta Santa* marble—Called thus because it was used for the jambs and lintel to the northernmost of the five entrances to St Peter's at Rome—the sacred entrance.

³ On the action of pozzolana Mr P. W. Barnett, A.R.I.B.A., of the Building Research Station writes as follows:—"When lime is mixed in the presence of water with certain materials such as pozzolana, trass, diatomaceous earth, finely ground slag or burnt clay, the result is a chemical combination of the lime and active siliceous constituents of the added material. This chemical reaction, not at present fully understood, is generally known as 'pozzolanic.' Such additives with pozzolanic properties are not mere aggregates or fillers; they impart hydraulic properties to the mixture, and the set product is a compound of greater strength than lime-mortar and possesses water-resistant qualities. The addition of a pozzolanic material to Portland cement is also of value since it replaces the vulner-

struction developed by the Romans. When the common clay or lime mortars known to earlier builders were used for masonry, the strength of the joint did not approach the strength of the stone. A homogeneous wall in stone or burnt brick was impossible under these conditions¹ and we shall see (iv. 7 and iv. 11) that the Egyptians and Greeks relied upon weight for adhesion. The Romans—owing to pozzolana—were the first builders able to command a joint as strong as the course. Hence the development of Roman concrete, a material in which the cement was acknowledged to be as powerful as the aggregate and therefore specially suited for vaults and domes. The pozzolana lay in thick stratas as it had fallen from the extinct volcanoes of the Alban Hills. Large beds are also found at Naples and Pozzuoli (Map, Fig. 6).

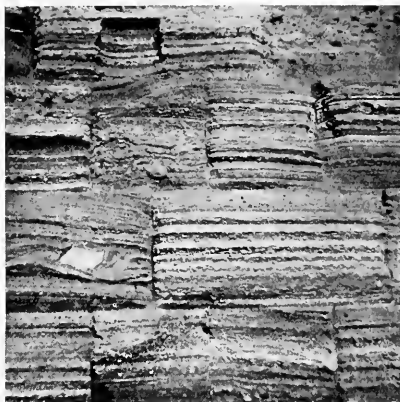


FIG. 17.—ROME. TUFA WALL. [H. B.]

Another volcanic material is tufa, a breccia or conglomerate in the nature of pumice, largely used in Rome in republican times. It was laid in large blocks and had to be protected from the weather by a plaster coat. Our illustration (Fig. 17) shows a tufa wall badly weathered from which the plaster coat has fallen away. The necessity to coat tufa for weather protection was one of the causes of the Roman plaster tradition. Tufa, owing to its lightness, was also a good material for vaults. In addition to tufa, peperino and Alban stone, also of volcanic origin, were frequently used. A volcanic stream had

able lime, set free during the setting of the cement, by compounds much more resistant to fire and to chemical destructive agents."

It is interesting to compare to this the words of Smeaton in the 18th century. In 1756, Smeaton made experiments on English limes, Dutch tarras (trass), and Italian pozzolana as ingredients, in order to discover the best hydraulic cement for the "Edystone" lighthouse. He decided on pozzolana brought from Civita Vecchia. "I perceived that in every state of it, if made into a mortar with Aberthaw lime, it exceeded in hardness any of the compositions commonly used in dry work; and in wet and dry, or wholly wet, was far superior to any." (Smeaton, J., *Edystone Lighthouse*, 1813, Book III., Ch. iv. p. 109.)

¹ But in mud-brick or clay-lump a homogeneous structure was possible and the Asiatic dome building was largely due to this fact.

III. 3. Theory and Elements of Architecture

brought to within three miles of Rome a useful lava known as selce (*silex*), very hard, gray in colour, and used from the earliest times and still used for paving Roman streets. (9) When broken and mixed with lime and pozzolana selce made the hardest concrete. North of Rome near Viterbo the extinct volcanoes have provided lavas and peperinos, used in all the buildings of the district.

Brick earth was plentiful and when mixed with a slight amount of pozzolana produced excellent bricks (v. 10).

The famous travertine (*lapis tiburtinus*) was a cream-coloured or brown-



[H. B.]

FIG. 18.—ROME. FINE TRAVERTINE ON THE CAPITOL.

coloured limestone capable of carrying great weights. Travertine is a river-bed deposit occurring in the valleys of the Tiber and the Anio. The most famous quarries were near Tivoli (*Tibur*) from which town the stone received its name. Fine travertine has a beautiful texture (Fig. 18), but the coarser kind (Fig. 19) is covered with cavities and therefore gives a natural key for plaster. This also tended to produce and maintain a plaster tradition among the Roman builders and many travertine buildings were plastered. Vasari suggests that travertine was infrequently carved as a decorative material until Renaissance times. (10)

The best cement was made by grinding and burning travertine and mixing the lime thus formed with pozzolana.

Owing to the excellence both of travertine and pozzolana the Romans were able to develop two techniques—a stone masonry and also a concrete-moulded.

The continuity of Italian building in all periods is due among other reasons to continuity in material. This can be well seen in the town of Verona where the magnificent Verona marble used by the Romans for beams, cantilevers, rock-faced walls, marble slabs, and paving stones, is to be seen put to the same varied uses by Renaissance builders and by modern builders.

Many Roman buildings, such as the Colosseum, became quarries of travertine from which the Renaissance palaces and churches were built. The outside walls and colonnades of St Peter's at Rome are built in travertine. In addition to the



[H. B.]

FIG. 19.—CHIUSI. COARSE TRAVERTINE IN THE OLD WALLS.

sources provided by ancient buildings the travertine beds near Rome were in continual use.

Certain formations of sandstone in Tuscany have played a great part in the history of building. Italian sandstone, known broadly as Macigno, is bluish grey or yellowish in colour and has local names. It is known as Pietra Forte and Pietra Serena in Florence and as Pietra Morte in the neighbourhood of Pisa. According to Murchison (11) it is of several varieties and passes from the Cretaceous into the Eocene Tertiary series. At Fiesole, near Florence, there are quarries (Fig. 20) that supplied stones of enormous size for the ancient Etruscan city (Fig. 21). The same large-sized stones are characteristic of the Florentine buildings of the fifteenth century such as the Strozzi and Pitti palaces ¹ (Fig. 22).

¹ Brunelleschi used Pietra Serena from Fiesole for the Badia church, the stone coming down hill from the quarries above.

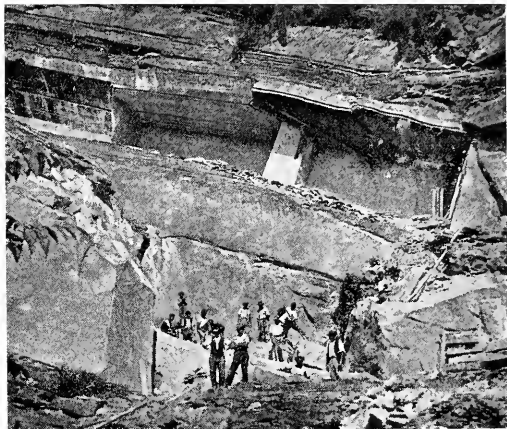
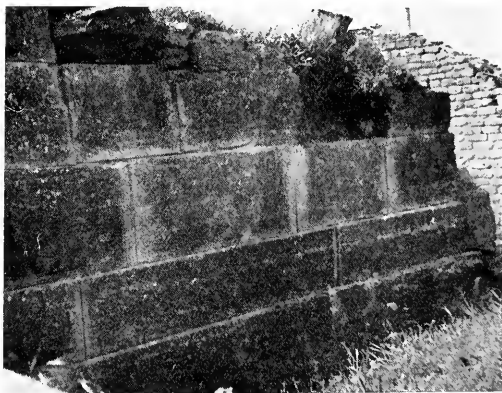


FIG. 20.—FIESOLE. QUARRY ON THE SIDE OF THE HILL.



[H. B.]

FIG. 21.—FIESOLE. BASE WALL OF ETRUSCAN TEMPLE.

The Romans at Fiesole used small square stones for their fortifications resembling the stone courses used in the Roman wall in Northumberland, and probably for the reason that in wall construction such courses enabled rapid slopes and changes of level to be followed with ease in hilly country. But the great Florentine builders of the fifteenth century reverted to the older custom and made full use of the magnificent banks of stone at their disposal. The massive walls and the rugged effects which they produced simply by emphasising their geological gifts are analysed in v. 6.

4. ITALIAN AND BYZANTINE MARBLES

In addition to the travertine and the macigno Italy has also produced a third material equally important. The Apuan Alps or Carrara Mountains form an independent massif on the gulf of Genoa joining the Apennines with the Sub-Apennines. The mountains are Permian and Triassic in age and consist of schists, limestones, and sandstones. But a period of violent earth movements, with a thrust from the south-west, has caused a series of folds and flexures which has twisted and even reversed the sequence of stratas, and the pressure under high temperature has converted the limestones into the wonderful crystalline marble horizons which, owing to the folding and subsequent denudation, now appear on the slopes and peaks. (12) Here are the marble quarries; the gaps hevn in them by the Romans from Augustus onwards, and by men of the Renaissance and modern times, can still be seen (Fig. 23). The white Carrara marble¹ was known by the Romans as *Marmor Lunense* from the ancient Etruscan city of Luna in the district and with it Augustus largely rebuilt and refaced Rome. The Medicis in Renaissance times reopened the ancient quarries of Polvaccio and the Fantiscritti



[H. B.]

FIG. 23.—FLORENCE. RETAINING WALL OF
THE PITTI PALACE.

¹ Carrara marble is sometimes known in England by the misleading term "Sicilian marble."

near Carrara; they were visited by Michelangelo, by Vasari, and other famous Renaissance sculptors and architects. On one such visit Michelangelo proposed to carve one of the peaks into a monument to himself.¹



[H. B.]

FIG. 23.—VIEW NEAR CARRARA OF THE "CANAL GRANDE" OR GREAT QUARRY WORKED IN ROMAN TIMES AND STILL IN USE.

The Apuan Alps have yielded at all times a variety of marbles—white, grey, pavonazzetto (peacock coloured), and breccia (mottled). To the north the district near Spezia yields a yellow and black veined marble now known as *portoro*. The Ligurian and Piedmontese green and vari-coloured marbles can be seen to-day in the churches of Genoa, also in the Superga church near Turin. At Susa the famous Roman church is built of serpentine.

From Verona came red and orange marbles, useful for every building purpose, as we have seen (p. 57). Verona marble, and Istrian marble used largely in Venice, weathers equally well when

cut into slabs and placed on edge as when placed on the natural bed. This fact profoundly influences design wherever it occurs since it produces slab walls (Fig. 69a) as well as course walls.

From the hills near Siena—now known as the Montagnola Range, similar in geological structures to the Apuan Alps (12)—came white marble and also the beautiful yellow known as Brocatello or Giallo di Siena, and hence arose a whole school of polychromatic design in Italy.

But the Roman discovery and exploitation of the Italian quarries followed upon their appreciation of costly stones won in Egypt. The conquest of Egypt at the close of the republican period had considerable influence on Roman ideas of material² and probably first revealed to the conquerors the idea of the precious monolith shaft and the use of figured stones. The change from the comparative

¹ Vasari. *Lives of the Painters*—Blashfield & Hopkins, 1897, vol. iv., Michelangelo, p. 70.

² Crassus, Lepidus and Scaurus (circa 90 to 60 B.C.) are mentioned by Pliny and others as being leaders in the new fashion for displaying foreign coloured marbles in their dwellings. Cf. the attitude of Horace in *Odes*, ii. 18.

simplicity of the Republic to the luxury and the passion for collecting, characteristic of the Empire, was due to the discovery in Egypt of what must have been to the Romans a new world of culture. As Roman conquests increased, and as provinces and quarries were added to the Empire, so the stones of Rome grew in colour and figure. Istrian marbles were carried across the Adriatic for Rome, as later for Ravenna,¹ and Venice. The stone buildings of Venice in all periods owe their character to the cream-coloured Istrian stone that takes a very fine joint, forms large slabs as well as courses, and weathers black and white not unlike Portland stone. The quarries at Trau or Tragutium in Illyricum, on the east shore of the Adriatic, provided a white marble resembling Istrian for the palace of Diocletian at Spalatro. The character of many Slav churches on the Dalmatian coast is due to the same material.

We have seen that the Romans opened up the Greek quarries for the sake of the coloured marbles ignored by the Greeks of the Classic period (iii. 2). The Romans also quarried the hills on the north coast of Africa. Here their most famous quarry was at Simittu Colonia near Tunis in Numidia, from which they extracted giallo antico (Marmor Numidicum) in colour a golden yellow. Simittu Colonia was a little mountain of marble entirely reserved for the city of Rome. Roman monoliths are still lying partially cut within it. It was surrounded by a wall and the ruins of a Roman city stand in its neighbourhood. The marble was dragged thirty miles to the coast from whence there was a continual transport to the marble wharves of Rome. Giallo antico was used as a wall-lining to the palaces of the Cæsars, as pavements in the Basilica Julia, and columns of this material are found in St John Lateran, the Pantheon, and the Arch of Titus. The Roman quarries along the coast of North Africa westwards from Tunis supplied also gray cipollino, rosso, and alabaster. (8) Blood-red marble and pavonazzetto were quarried at Synnada in Phrygia.² Granite was had from the island of Elba, gray in colour. Seven of the eight monolith columns in the front row of the Pantheon portico are said to be in Elba granite.

The supply of precious building-stones for so many centuries made Rome into a veritable mine of marble, and in medieval times the façades of Pisa and Orvieto were built of marble taken from Rome and Ostia.³

¹ Istrian limestone was used also in Ravenna; the monolithic cap covering the tomb of Theodoric is of that material. (Rivoira, *Lombardic Arch.*, vol. i. p. 54.)

² The columns of the Basilica Aemilia in the forum at Rome were said by Classic writers to have been of Phrygian marble.

³ Lanciani, *Golden Days of the Renaissance in Rome*, 1906, p. 48.

After the State conversion to Christianity such Roman temples as were not adapted to Christian worship were at first preserved by Constantine's decree as a species of sacred museum but later were plundered and allowed to fall out of repair, and they in their turn became quarries for the early Christian and Byzantine builders. Famous monoliths, brought to Rome from Egypt, were, after centuries, transferred to Constantinople and there took their place in the religious and secular structures of the eastern empire. The great sea-wall of Constantinople is bonded with the shafts of classical columns, and marble columns are laid horizontally as bearers in the foundation of the bastions where they project into the sea. Early Christian churches were generally built to suit whatever set of Roman shafts were procurable at the time for their nave arcades. Constantinople, Ravenna, Venice, and finally Renaissance Italy, continued to use these sources.

But though their shafts were at second hand the Byzantine builders crowned them with capitals in a new manner. The old columns used again had now to carry the springing of two arches instead of the old Classic lintel. The Byzantine builders carried the arches on an intermediate cushion block known as a *pulvino* or *dosseret*. This pulvino when placed upon an ancient column—even without first removing the original cap—converted it in a flash from pagan to Christian. The pulvini were made of white marble and were sent out like missionaries from Constantinople all over the Christian world. They were supplied from an inexhaustible island of fine Eocene marble near Constantinople called Proconnesus, and the quality of this marble soon led to the intricate carving characteristic of Byzantine caps. At the later church of St Apollinare at Ravenna (Fig. 23a) the practice which was originally a make-shift has become an established treatment. The nave arcade consists of Corinthian columns each capped by a plain pulvino marked with a cross. The two ranks stand like converts and are indeed symbols of a Classic world converted to Christianity.

But Proconnesan marble was chiefly used in the great church of St Sophia in Constantinople where it is found externally and internally. So great was the transport of marble from Proconnesus ¹ that the island and the sea became known as the island and sea of "Marmora" or "Marble."

The lining of Byzantine churches with thin sheets of coloured marble caused the continuous working of the ancient quarries for figured stones. Many of these

¹ The marble of Proconnesus was said by Pliny to have been used by King Mausolus in the building of his palace. The Mausoleum of Halicarnassus is also said to have been of this material though the quadriga at the top (now in the British Museum) is of Parian.



FIG. 23a.—RAVENNA. ST APOLLINARE NUOVO, NAVE ARCADE.

[Rev.]

III. 4. Theory and Elements of Architecture

were specially procured for the interior of St Sophia—porphyry and alabaster from Gebel Dukan in Egypt; verde antico from Atrax in Thessaly; green porphyry from Mount Taygetus; green cipollino from Mount Carystus; giallo antico from Simittu Colonia in North Africa, and various marbles from the Ionian shores and islands (13). *See* Map Fig. 6.

Procopius says of the marbles of St Sophia: "Or who can reckon up the splendour of pillars and stones with which the fane is adorned? One might fancy oneself to have happened on a lovely mead of flowers. One might duly admire of some the purple, of others the green; and in some the bloom of crimson, and in some white flashes out, while nature, like a painter, tricks out the rest with contrasting tints."¹

5. MESOPOTAMIA AND PERSIA (10)

The region forming the link between Europe and Asia—that is to say between the Black Sea and the Caspian on the north, and in the south extending

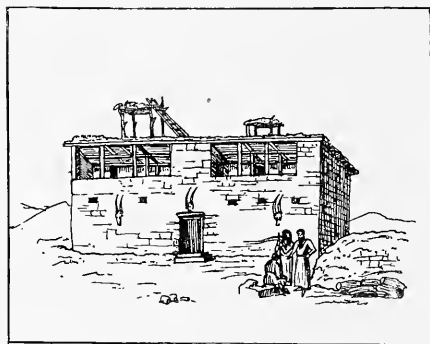


FIG. 24.—ARMENIAN HOUSE IN THE DISTRICT OF TIYARI. (After Layard.)

from the mediterranean eastward to include the Persian and Kurdish highlands—is a tract at least as important in the history of structure as the Nile Valley. It was itself the parent of distinct civilisations but was also the highway between east and west.

A peculiar climate characterises it. Its inhabitants suffer from violent extremes of heat in summer and cold in winter. These conditions are important. Layard travelling in Kurdistan in 1845 gives a description of how these

extremes of climate directly influence the house building of the native Armenian in the district of Tiyari where timber was then to be had (Fig. 24). "The houses are simple and constructed so as to afford protection and comfort during winter and summer. The lower part is of stone and contains two or three rooms inhabited by the family and their cattle

¹ Procopius' Panegyric on the Edifices of Justinian: quoted by Jackson in *Byzantine and Romanesque Architecture*, vol. i. p. 84.

during the cold months. Light is admitted by the door and by small holes in the wall. There are no windows, as in the absence of glass, a luxury as yet unknown in Kurdistan, the cold would be very great during the winter when the inhabitants are frequently snowed up for many days together. The upper floor is constructed partly of stone and partly of wood, the whole side facing the south being open. Enormous beams resting on wooden pillars and on the walls, support the roof. This is the summer habitation and here all the members of the family reside. During July and August they usually sleep on the roof upon which they erect stages of boughs and grass resting on high poles . . . the winter provision of dried grass and straw for the cattle is stacked near the dwelling or is heaped on the roof." (15)

The rigorous climate which thus acts upon the comparatively modern house, produced in the past, in conjunction with an absence of timber, a school of design which had far-reaching results.

On the map of building materials (Fig. 6) we should look first at the margin between the Persian plateau and the rich alluvial plain of Mesopotamia at its foot. Here the highly skilled mud-brick builders of the plain were continually mixing with Persian mountaineers who were good stone builders.¹ They had in common the fierce climatic conditions which we have emphasised, namely great extremes of heat and cold, and also of wet and dry, the former predominating in the hills, and the latter on the plains. But they had very different sources of building material.

In Mesopotamia the alluvial mud of the Tigris and Euphrates and of their connecting streams is as fine a brick earth as the Egyptian mud; stone however was scarce, occurring only in occasional ridges of sandstone and gypsum.² Bricks therefore,³ had a special value and became almost sacred, having a god of their own. (17) The rainfall which was diluvial was countered by a fine system of

¹ The mud-brick builders of Assyria had also on their west a stone-building people namely the Hittites. These people had used sandstone blocks 8 feet long at Boghaz Keui; and at Carchemish had built orthostat walls of basalt and limestone. (16)

² Assyria in the north, near the Taurus Mountains, had stone nearer to hand yet followed closely the Chaldean construction. The huge slabs of alabaster on which the lions of Nineveh were engraved were brought down the Tigris from the Armenian hills. Black basalt "abounds in the Kurdish hills and particularly in the neighbourhood of Jezirah (the ancient Bezabde) and in that part of the Taurus through which the Tigris and Euphrates find a narrow and sudden outlet into the Assyrian plains." (15) Mr C. L. Woolley mentions that at el Obeid there were in Sumerian times "quarry shaped blocks of limestone" used for footings, and steps of "hard white sandstone." (18)

³ For the supply of clay for bricks see Mr Woolley's note, p. 104.

III. 5. Theory and Elements of Architecture

drainage (17) and by the use of bitumen—a natural asphalt occurring at many places on the plain but especially at Ur and at Hit.¹ Both bricks and slabs used for flooring were set in joints of bitumen mixed with earth. (18)

Persia had almost all the building materials in equal inaccessibility—fine limestone (difficult to transport owing to the steep inclines of the hills), timber



[From Dieulafoy's "*L'Art Antique de la Perse*,"

FIG. 25.—ISPAHAN. "THE HALL OF MIRRORS," PALACE OF AINAKÉ. A TALAR OR AUDIENCE-ROOM BUILDING.

only by careful afforestation, and mud-brick in the ravines of the mountains. Hence a certain initial eclecticism in Persian architecture. We have already noted (ii. 7) that the long banks² of Persian limestone made possible the tall characteristic, Ionic-like, shafts. A type of ancient building, consisting entirely of columns such as the Hall of Xerxes at Persepolis, found both in Persia and Mesopotamia and

¹ See Map, Fig. 6.

² "Bank" is a term for the uninterrupted strata of stone occurring in a quarry the sizes of which, in height and length, naturally limit the sizes of stones procurable in one piece, *i.e.* sizes of monoliths.

still well known as a *talar* or audience-room type in the East (19) (Fig. 25), was supported in ancient Persia on stone columns. Here we find the Asiatic form of the ceiled colonnade referred to (ii. 1) as a climatic building-form induced by bright sunlight. The winter rains in Persia were countered by carefully laid stone platforms with a system of drains beneath them. (19) The masonry of the famous Achemenid platforms at Persepolis and in the valley of the Polvar (20) rival, and correspond with, Greek masonry of the best period. Stone was also used for the doors and windows and for the angle piers of structures having mud-brick walls.

All this suggests a high degree of masonry and general building technique and adaptability among the Persians. Both Persia and Mesopotamia were ill

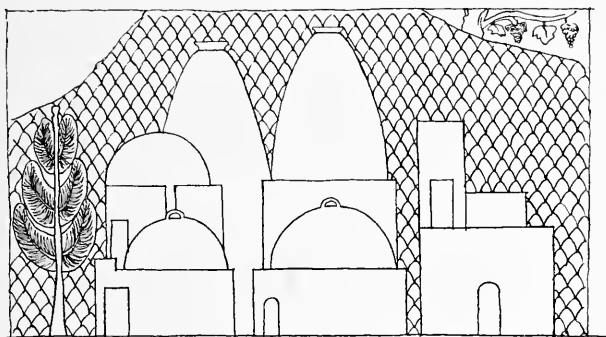


FIG. 26.—DOMES FROM AN ASSYRIAN RELIEF. (After Layard.)

provided with building timber and both had an early knowledge of the arch for small spans. The result of these conditions was nothing less than the eastern development of the vault and dome. The plasticity of the Mesopotamian mud was the chief factor. Domes both semi-circular and egg-shaped and crowned with small eyes or lanterns (Fig. 26) are seen on the Assyrian reliefs and were evidently a well-recognised type at a very early date. The scarcity of timber also required that the dome or vault should develop, if at all, without centering; and we find as a result that the characteristic of the "eastern" vault is an ingenious inclining of the arch rings for that purpose (Fig. 27). Now the two building facilities we have discussed—the mud-brick and the masonry—were well mixed and transposed by the succession of Persian conquests and dynasties which covered the whole region—Achemenid, Alexandrian, Seleucid, Parthian, Sassanid. Finally

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there emerged the great "Persian" vaulted buildings found along that strategic margin of hill and plain at Hatra, Susa, Chuster, Ctesiphon (Fig. 4a), and at Sarvistan (Map, Fig. 6). The necessity to provide against summer heat and winter cold produced in the vaulted building the characteristic plans having very large and very small apartments close together. Extremely thick coverings also

were necessary. If the climate of Egypt by its beneficence is a chief factor in modern civilisation so also is the peculiar brutality of climate in Iran and Mesopotamia.

Two widely separated schools of building each with its supply of a material characteristic to itself, helped to develop and radiate the eastern vault and dome. These we must now glance at.

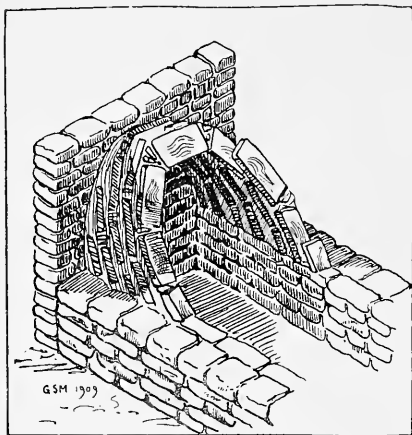


FIG. 27.—VAULT WITH INCLINED RINGS.
(From Mileham.)

6. ARMENIA AND SYRIA

The deforestation of the Near East—of Lebanon, Amanus and the Taurus Mountains both removed a native roofing material and sharpened the extremes of climate (p. 35).

The eastern domed and vaulted structures, the origin of which we have just analysed, came westward and northward therefore, in response to a real need. Two districts in the region we are considering had stone supplies which enabled them to make special contributions to vault design. (21) Ancient Armenia in the north (deforested at an early period) had limestone, and not far distant black basalt and sandstone. (21a) The sizes of stones obtained were large. The stone-jointing was good and also rubble concrete was used in dome construction. In the Armenian churches at Ani, Erzerum, Edschmiazin, the eastern vault and dome was turned to Christian uses and given a marvellous variety and beauty on a small scale.¹ This was due among other factors to using large-sized stones

¹ Strzygowski directly attributes the Armenian stone dome to the absence of timber :—"It would seem that in Iran a decisive influence was exerted by East-Aryan prototypes in wood construction, such as we can still trace in the Ukraine, in Kashmir, and in India. In these countries the builder roofed a square

for comparatively small buildings. The Armenian churches came to stand for a powerful school of Christianity very early in the Christian era, and Armenian building forms, carried across the Black Sea, penetrated along the great trade routes into Russia and the regions of the Baltic. Here owing to their small size they were easily imitated again in wooden construction.

Syria on the eastern margin of the Mediterranean between the Arabian desert and the sea was an influential building centre for two reasons. Fine

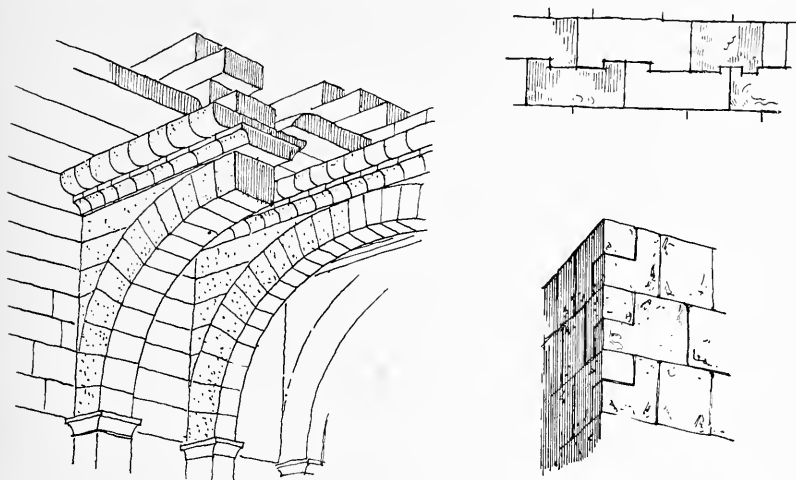


FIG. 28.—EXAMPLES OF ANTI-EARTHQUAKE CONSTRUCTION. (*After De Vogüé.*)

building stones—a limestone near Antioch, and a basalt beyond the Jordan (*see* Map, Fig. 6)—caused the early development of a masonry technique of the first quality in the hands of Hellenistic and Roman builders. The region lay also directly on the trade route between Egypt and Persia. Here also timber seems to have been scarce even so close to Lebanon and Amanus before the opening of the Christian era, although the serious deforestations of Lebanon did not occur until the sixth century A.D.

plan by corbelling with short beams. As soon as this style of construction entered countries without timber, like Iran and the Armenia of Christian times, this corbelling was executed perforce in unburned brick or in rubble-concrete.” (21) Compare the timber building of the Colchi, p. 35.

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A vital building factor in Syria was the frequent earthquake, and here a highly developed anti-earthquake construction in masonry may be studied. (22) Sometimes the ground floors of buildings were cut out of the live rock and the stone thus obtained used for the first floor and for the beams of the roof. Stones of very large dimensions were quarried. For the sake of stability stones were cut with special joints (Fig. 28) and sometimes housed into each other. A masonry framework of large span arches having heavy abutments was combined with short span lintels and stone panels which in many cases have sustained the shocks of centuries.

Syria, converted to Christianity, became the centre of early monasticism. Churches, baptisteries, monasteries, gave a new impulse to building. The indigenous population, largely Semitic and always in touch with the East, favoured the eastern vault and dome which enabled all classes to dispense with timber. But the great Hellenistic masonry traditions existing in Antioch and the Haouran made these "eastern" vaults, when adapted to basilicas and churches, the finest of their kind and enabled them to resist earthquakes. Syria, equipped with these great stone structures embodying the "west" and the "east" in almost equal proportions, survived the Islamic conquest and remained to exert through monasticism a constant, quiet, but powerful influence on the church builders of Europe in their early struggles to vault wide spans.¹

7. MEDIEVAL BUILDING STONES

We have seen that the Romans largely owed their mastery of vault construction to the natural cement known as pozzolana and to the light tufas (iii. 3). The problem in design before the builders of the monastic age was to imitate Roman vaults without pozzolana. The Romans had left two great building legacies to the Christian world—the groined and buttressed vaults of the great Baths inscribed to Diocletian and his colleagues (Fig. 28a), and the stone quarries

¹ The balance of evidence seems to be against the theory that the Crusaders were the chief means of conveying oriental influence to the western schools of design. The influence must have been earlier. De Vogüé, speaking of the Romanesque builders says:—"The intelligent imitation of Roman ruins is not sufficient to explain their rapid progress. They found the ground prepared by three centuries of obscure efforts made in the only country which could, at that time, furnish masters—namely the East. It was in that preparatory and obscure period that I for my part would place the direct agency of the oriental schools upon the art of the West—an agency which was exercised not only by reason of commercial relations and importations of objects of luxury, but by reason of the emigration of artists driven out by the iconoclasts or summoned by clear-sighted patrons of art." (22)

of Gaul. It was important to vault a monastic building in the tenth century because it held, as in a chrysalis, the civilisation of Europe. Books were in the cloisters, paintings in the chapels, medicines in the dispensary. Outside was the constant threat of fire and sword, and the danger of fire was increased by a wood roof. A glance at the map (Fig. 6) shows that dwellers upon the Lombard plain had in the valley of the Po, and as far south as Ravenna, alluvial earths suitable

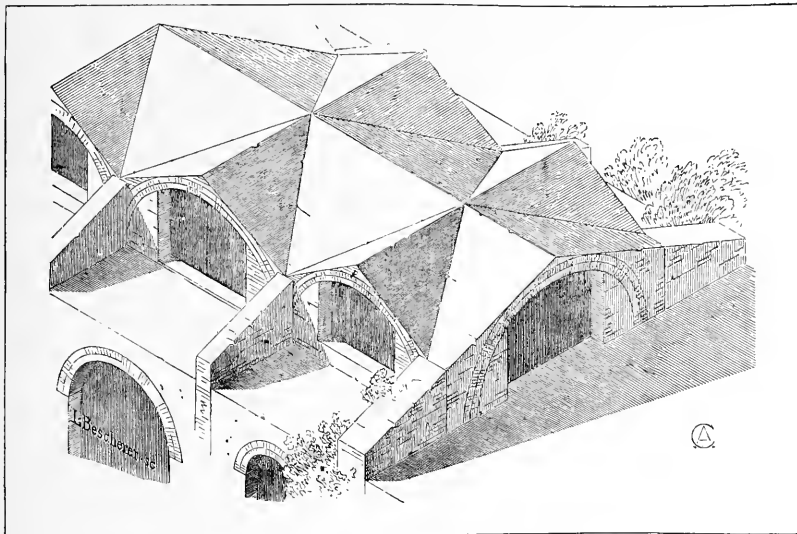


FIG. 28a.—BATHS OF DIOCLETIAN. (*From Chiosy.*)

for bricks and terra-cotta. Here, at a later date, the fine brick and terra-cotta styles of the late Middle Ages and Renaissance developed, as in the towns of Milan, Pavia, and Bologna. The early Lombard builders taking advantage of their soils, invented a light spiral vault constructed of earthenware tubes with which they covered many of their brick churches. (23) An example is given of the dome over the octagonal church of St Vitale at Ravenna (Fig. 29). In Lombardy pozzolana could be procured from the south. (23) But it was otherwise in Burgundy, in the valleys of the Seine and the Rhine, and in Normandy. Here were fine stones but no special ingredients for concrete. On the other hand the Romans had been

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the most intelligent exploiters of quarries in all countries where good stone was

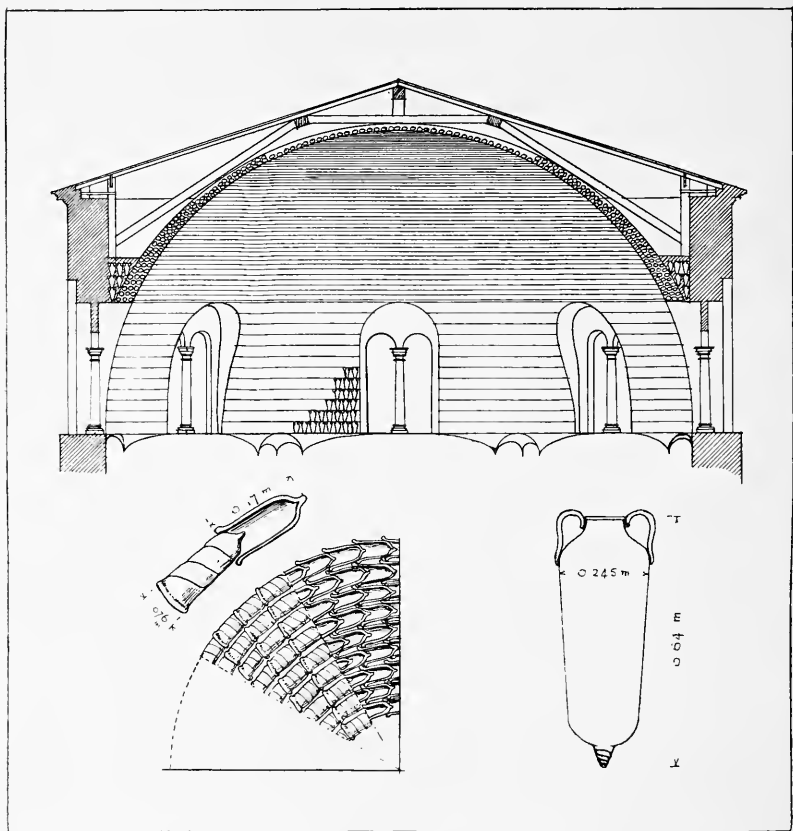


FIG. 29.—RAVENNA. ST VITALE, DOME BUILT OF EARTHENWARE POTS. (After Gailhabaud.)

to be had.¹ “There does not exist a Roman building in which the stones are

¹ In England the Blackpasture sandstone quarries in Northumberland were originally used by the Romans for the bridges over the north Tyne and have recently been used for restoring Durham Cathedral. The magnesian limestone quarries near Tadcaster were also originally used by the Romans.

second rate . . . if building-stone is wanted in any country in which the Romans have left monuments it is only necessary to seek out the Roman quarries." (24)

Building-stone, however, was precious, and transport was expensive, so that we find the great monasteries like the Classical cities generally near quarries.¹ The small sizes of stones used, the large mortar joints and the round arch (v. 7), at first preserved the Roman tradition. This is recognised in the term "Romanesque" generally applied to monastic architecture out of Italy. But different stones soon produced distinctions. In the valley of the Rhine the sandstones and grits from the hills of the Black Forest on the east bank, and from the Vosges on the west bank, were carried down the river for building, and contributed to the broad, massive character of Spires, Worms, Mayence, and the Rhenish school generally. A sandstone and fortress-like Romanesque is also found in the north of England at Durham and Lindisfarne, outposts of Christian culture. Compare these to the brickwork of St Albans on the edge of the London clays, more Italian in character without and within, and this again to the elaborately carved "Caen stone" churches of Normandy. The soft Caen stone, quarried in Calvados, was shipped easily to English river mouths and gave to Norman and Anglo-Norman alike its highly decorative character. Granite of the same geological character occurs in Cornwall and Brittany and gives to church types in those districts a certain resemblance. The most distinct granite architecture in France is that of the early Auvergne churches. Both the landscape and the architecture in Auvergne are caused by the basalt and granite formations. The small complete churches built of large stones and decorated with coloured lavas, such as Issoire, Le Puy (Fig. 30), and Notre Dame du Port at Clermont are typical examples of the influences of the geology on the design.

Gothic, however, was the result of limestone.

The geological map of France—the arena of Gothic—shows a rich quality and a rich variety in limestones. (25) Gothic architecture came about, structurally, through the progressive concentration of loads upon points and also through the discrimination and selection of stones for that purpose. This was made possible by the limestone resources, found chiefly in the Jurassic system and in the systems of Tertiary age. The Tertiary are limestone beds of Pliocene, Miocene and Oligocene series, originally deposited by great lakes. The three regions of these deposits are roughly shown in the map (Fig. 6). In the north the basin of the Seine and its tributaries gives the famous stones of the Isle de France which are

¹ "The parent monastic house of Cluny, established in the Jurassic region, and likewise Clairvaux, seemed to impose on their daughter houses the necessity of building near rich quarries." (24)

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generally soft and easily cut when first quarried. Paris is a quarry as well as a city. Amiens Cathedral is built from quarries at Bonneleau; Rouen from quarries at Vernon, and Chartres from Berchères, all situated on the Tertiary limestone. In the south-west occurs the basin of the Garonne supplying



FIG. 30.—HAUTE-LOIRE. CATHEDRAL OF LE PUY.
(Archives de la Commission des Monuments Historiques.)

Bordeaux, and a less extensive deposit is found in the lower valley of the Rhone supplying Marseilles, Arles, Nîmes, Orange. Round each of these "lakes" is a Cretaceous shore varying in width and supplying chalk. In the north this chalk causes the white cliffs of Normandy and Kent. Round the Cretaceous again we find the important margins of the Jurassic. The Jurassic stone is harder than the Tertiary stones. The main Jurassic drift can be followed on any geological map of Europe (26), from the Jura Mountains (whence its name) north-

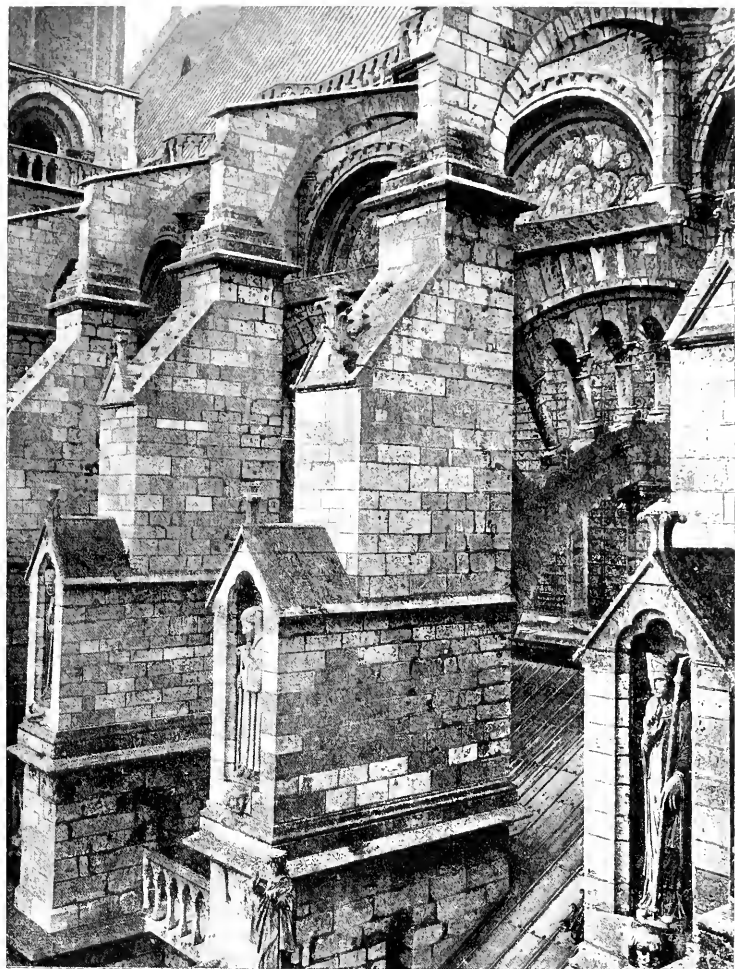


FIG. 31.—CHARTRES. SOUTH FLANK BUTTRESSES.

[Et Houvet.]

III. 7. Theory and Elements of Architecture

east to the Upper Meuse valley, then skirting the Cretaceous system clockwise to Caen, then under the channel to the Isle of Portland, to the Cotswolds, and thence in a diagonal band across England to the Yorkshire coast. This course may also be followed on the materials map (Fig. 6) in limestone buildings roughly



FIG. 32.—NOTRE DAME DE DIJON.
INTERIOR SHOWING TRIFORIUM.

as follows: Dijon, Vezelay, Auxerre, Bourges, Poitiers, Le Mans, Caen, Portland, Sherborne, Bath, Malmesbury, Bloxham, Kettering, Peterborough, Stamford, Lincoln, Malton. Again, retracing our steps, a band of the Jurassic in France, bordering the Garonne basin follows a line south-east of Poitiers—a line marked by the famous domed churches of Angoulême, Périgieux, Souillac.

The Jurassic of Burgundy provided, in such quarries as Coutarnoux on the Yonne, a hard limestone giving stones of large size. In the church at Vezelay this stone was specially selected for monolith shafts carrying weight, although stones of a softer character were nearer at hand. (24) Stones used thus for monolith shafts were set not on their

natural bed but vertically. The courses forming the walls were set most carefully on their natural beds, and beds giving different sizes were selected for various purposes. The movement was thus towards thinner and more scientific walling, and in the fully-developed Burgundian Gothic we find, as at St Etienne Cathedral Auxerre, and Notre Dame de Dijon (Fig. 32), that the clerestory and triforium have become a hollow boxing (Fig. 32a), and that almost every stone of the structure has a function of its own.

In the Isle de France the same process can be studied, notably at Chartres, where the large "banks" of the Berchères quarries supplied stones of all sizes. This selecting of stones for different positions is seen in the Chartres buttresses (Fig. 31).

In England the abundance of Purbeck and Petworth marbles supplied

monolith shafts (27) capable of carrying great loads if properly stayed. The nave piers of Salisbury for instance have groups of four marble shafts to each pier stiffened by brass rings at the joints tailed into a central pier of masonry.¹

Gothic construction, owing to a progressive exploring of stones, had become by the middle of the thirteenth century, a masonry skeleton having a light panelling or filling between the bones, and no longer bore resemblance to the massive moulding of structural units characteristic of Roman construction.

In the district of the Bourbonnaise, situated between the volcanic of Auvergne and the Jurassic of Burgundy, an interesting brick style developed owing to the lack of stone. Here, it is said the diaper patterns in brickwork (p. 166) are first found, as in the castle of Lapalisse and in Moulins. (24) But it is in the south of France that the most important and striking brick style occurs. In the basin of the Garonne and its tributaries, and on the border of the Gulf of Lyons, brick earths occur in the Tertiary deposits we have noticed. Corresponding to these we find considerable brick buildings at Toulouse and Albi, at Simorre, and on the coast at Perpignan. The magnificent brick churches of Albi (Fig. 32*b*) and Perpignan (Fig. 33) have little of the Gothic skeleton construction owing to their material,

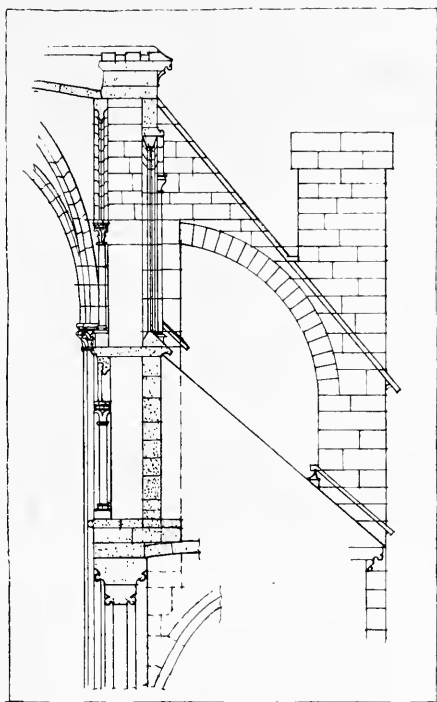


FIG. 32*a*.—NOTRE DAME DE DIJON.
SECTION THROUGH NAVE. (After Viollet-le-Duc.)

¹ The question whether the monolithic shafts in England were designed to carry weight or were inserted for appearance sake after initial settlement is controversial. (27)

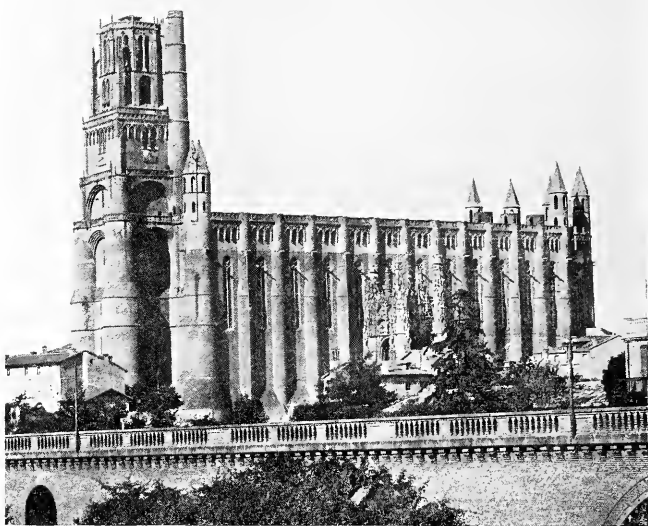
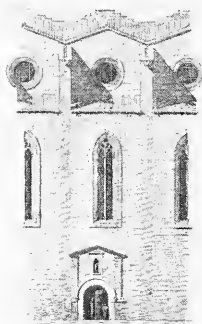


FIG. 32*b*.—ALBI. FROM THE SOUTH.



Mayeux del.]



[Cliché Ch. Schmid et H. Laurens, Eds.

FIG. 33.—PERPIGNAN. ELEVATION AND SECTION.
(Archives de la Commission des Monuments Historiques.)

and in character resemble much more the moulded Roman. The resemblance between Perpignan and the Baths of Diocletian (Fig. 28*a*) is striking.

Spain, a tableland traversed by mountain ranges, has also a series of Tertiary deposits (28), largely of the Upper Miocene series, occupying the sites of vast lakes formerly extending between the mountain ranges and now constituting the main river basins. (7) Good varieties of limestone are found in these deposits and there are limestones earlier in age. Granite is distributed in the north-west and centre—in Galicia, in the Castiles, and in Extremadura.

To these two chief stones, the granite and the limestone, correspond two very marked building tendencies in Spanish architecture, namely the massive constructive on the one hand, and the highly decorated on the other. Broadly the notable Roman and the Romanesque structures are found in the granites, the Gothic in the limestones, and some Renaissance buildings, such as the Royal Palace at Madrid and the Hospital of Santa Cruz, combine the two—for their appropriate uses.

The best limestones are found in Castile and the mediterranean zone.¹ In the province of Burgos the white, close-grained, limestone from Ontoria de la Cantera has produced Burgos Cathedral. The cathedrals of Leon and Palencia are in limestone but of a quality poorer than the Ontoria stone, and Oviedo Cathedral is probably built of the carboniferous limestone upon which it stands. A limestone Romanesque school is found in the Douro basin having its source at Soria. The city of Madrid was largely built of Miocene limestone from the quarries of Colmenar de Oreja and known as Piedra de Colmenar. This is a compact and brittle stone which takes on a very beautiful ivory appearance with time. The marble-like limestones of the mediterranean zone contributed to the fine Romanesque style of Catalonia and the transition Gothic of Valencia. In the south of Spain the soft yellowish limestone known as "piedra franca" from the Sierra de Cordova and other beds has been used in all periods and styles. The famous Mosque of Cordova built by the Moors is in "piedra franca."

The Moorish builders applied tablets of fine-grained sandstone upon the limestone structure for ornamental purposes, the reason being that the piedra franca when carved offered too slight a resistance to weather. A compact white limestone exists in the south from which the cathedral of Malaga is built. The Renaissance cathedral of Granada is built of white and of yellowish limestones.

¹ These and the ensuing paragraphs follow closely some notes communicated to the authors by Senor Pablo Gutierrez y Moreno. Only a fraction of his information, owing to space, can be given here, but copies of the full notes are placed in the library of the Architectural Association for the use of students.



[F. R. Y.]



[F. R. Y.]

FIG. 34.—SPANISH LIMESTONE (BURGOS CATHEDRAL) COMPARED WITH SPANISH GRANITE (ESCORIAL MONASTERY).

All the Gothic work of the Cathedral of Seville is of a sandy limestone, yellowish in colour but darkened by time; this stone was obtained from several quarries, mainly from that known as the Giant's Cave in the Sierra de San Cristobal in the Province of Cadiz. The Renaissance and Baroque additions to Seville Cathedral are of a white limestone quarried at Moran in the Province of Seville and elsewhere.

Near Segovia on the central range both granite and limestone are found. In the Roman epoch granite was the building stone, and the famous Segovia aqueduct is built of it, but with the downfall of the Roman power in Spain granite disappeared until the end of the fifteenth century when it was again used either alone or in conjunction with limestone. The Romanesque architecture of the city of Segovia and its cathedral are of limestone of the province, probably from quarries in the neighbourhood of Sepulveda. The granite of the central range is generally called "piedra berroquena," and is largely used in Avila, Toledo, and Madrid. The Monastery of the Escorial (Fig. 34), set as it is in the midst of granite masses and built of the same material, is an example of its influence upon design.

In Galicia the whole of the architecture is of granite which locally is given the significant name of "building stone." The characteristic styles of the region are Romanesque and Baroque, both characterised by a massiveness derived from the material. Gothic does not appear to have found any real footing in Galicia. Santiago de Compostella, a Spanish city rich in monuments, is built entirely of granite. The towns of Vigo and Corunna are also built of granite.

Spanish polychromatic design, both external and internal, is due to the wealth of jaspers, serpentines, alabasters, and green porphyries.



[R. C. B.]

FIG. 34a.—THE ALHAMBRA. COURT OF THE LIONS.

Spain is specially rich in marbles. Granada in the south became the centre of a fine medieval culture under the Moors. It was rich in all kinds of building materials. The Granada marbles had already been discovered by the Romans. From the quarries in the Sierra de Cordova, the Sierra de los Filabres and the Sierra Nevada, the Moors lined and colonnaded the interior of the Alhambra (Fig. 34*a*) and other monumental buildings in Cordova, Malaga, Granada, and Almeria.

Gypsum was ground and used by the Moors for their ornamental plaster work. Brick architecture in Spain developed on the plains of Castile and in the Ebro and Guadalquivir basins where brick earths are found. Hence the brick architecture of Aragon and of Seville. The true architecture of Seville is the architecture of brick, tiles, and of plaster work. Ceramic art was used in Seville in order to reproduce exotic forms adapted from distant stone design.

8. BRITISH STONES (29)

We have already noticed the extension of the Jurassic system from France across England in a diagonal band from the Dorset to the Yorkshire coast (p. 76). This system with its wealth of limestones is, from a building point of view, the geological backbone of England. The three principal groups into which the limestones fall are (*a*) the Upper Jurassic, yielding the Purbeck, Portland, and Vale of Wardour stones (Chilmark), generally of a shelly nature; (*b*) the Great Oolite¹ of the Middle Jurassic yielding the Bath, Box, Corsham, and other well-known stones of that group; and (*c*) the Inferior Oolite of the Middle Jurassic yielding the Ham Hill, Doulting, Ketton, Barnack, and the "Lincolnshire limestones." To these three might be added the calcareous sandstone of Yorkshire (of the Middle Jurassic) from which St Hilda's Abbey at Whitby was built. The distinctive English Gothic with its profusion of undercut mouldings, its moderate-sized courses, and its variety of surface tones—is first due to the variety and tractability of these limestones.² Purbeck marbles also belong to this system and supplied the monolith shafts, which as we have seen (p. 77) played a considerable part in the developed Gothic construction. Tufas, where they could be had were put to their traditional uses of vaulting, owing to their lightness: the vault

¹ "Oolites" or "roe-stones" from their resemblance in texture to the roe of a fish.

² The following churches are some of those built in Jurassic limestone: Salisbury (Chilmark); Wells (Doulting); Bath Abbey (Bath quarries); Christchurch, Oxford (Guiting); Peterboro' (Barnack); Ely (Barnack); Upper part of King's College Chapel, Cambridge (Weldon); Kettering (Glendon); Gloucester (Brockhampton); Sherborne Abbey (Ham Hill); Lincoln (Lincoln quarries); Malmesbury Abbey (Box Ground); Stamford Churches (Ketton); Winchester (Doulting).

webs of Bredon porch and of Sherborne were originally of tufa (27). Chalk, being light, was also used in vaults as in Canterbury and Salisbury cathedrals.

Taking the Jurassic band as a datum, the geological systems, younger in age, lie above it roughly to the eastward, and the older, below it, to the westward and northward. To the eastward "the chalk" or Cretaceous system lies next above the Jurassic and this in turn surrounds and underlies the London clay of the Tertiary age. The Cretaceous extends from Norfolk south-west through the Chilterns and Salisbury Plain, to Dorset and then eastward to Kent; it gives the famous flint churches of Norfolk (Fig. 34*c*), the soft clunch or Totternhoe stone of Bedfordshire, the ragstone of Kent, and the gault bricks of the nineteenth-century house. In the Cretaceous districts such as the Chilterns, and Wiltshire, walls built of chalk and flints bonded with bricks are common. The interior of Salisbury Cathedral shows a combination of three materials: the piers consist of Purbeck shafts round a centre pillar of Chilmark limestone, the spandrels of the arches and the aisle walls are in limestone and the panels of the vault are of chalk (Fig. 34*c*). In Kent the Cretaceous system provides nearly all the materials necessary for a great school of building. The chalk is easily burnt for lime, there are outcrops of sand and gravel along the greensand, the ragstone and the "Tonbridge Wells" sandstone are useful masonry materials, the oak flourishes, and on the Weald the clay makes excellent bricks and tiles (Fig. 34*b*). In consequence of this all the building motives are found in common use in Kent—the lintel, round arch, segmental arch, depressed arch, arch and lintel in combination, and high and low-pitched roofs. This variety of building motives is generally the sign of a wealth of material. In Kent also at the junction of the gault clay and the chalk, Portland cement factories are found.

The Tertiary in England, unlike the series of the same age in France, supplies no limestones; its chief building product is brick-earth on the London clay series and Thames gravels. Hence the walls of London stock-bricks and of Reading bricks and the brick buildings of Essex (Fig. 34*c*) dating back to Roman times.

In the west and north the Trias, Permian, and Carboniferous systems underlie the Jurassic in the order given. To the north, in the Permian system, a band of magnesian or dolomite limestone extends from near Nottingham at its southern extremity to the coast of Durham. Its track in buildings can be followed thus: St Mary's, Nottingham; St George's, Doncaster; Tadcaster town; Roche Abbey; Huddlestons Hall; and churches at Ripon and Darlington. In addition to these, Southwell Minster, Selby Abbey as re-built, and York Minster and



"Tunbridge Wells Sandstone," Goudhurst.



Brick—near Sandwich.



Half-Timber Work, Elham.



Squared Ragstone, West Malling Church.

FIG. 34b.—EXAMPLES OF VARIOUS KENTISH BUILDING MATERIALS SUPPLIED BY THE CRETACEOUS SYSTEM.

Guildhall are built in magnesian limestone, also part of King's College Chapel, Cambridge (7), the Houses of Parliament, and the Geological Museum in London. It is a fine-grained stone, brown or yellow in colour, good for Gothic in country districts if properly selected. It is liable in large cities to decompose rapidly both on the surface and through planes of cleavage.

The sandstones and grits ¹ are found in the Triassic, Permian, and Carboniferous systems. The New Red Sandstones of the Trias and the Permian systems have been used in Chester Cathedral and town, and are now being used in the new Liverpool Cathedral. In Cumberland "Penrith sandstone" can also be seen in ancient and modern buildings.

A sandstone Gothic differs from a limestone Gothic. The sandstone is harder and reflects less light at its surface. Liverpool Cathedral, built from the Woolton quarries, shows the development of the Gothic design to suit the material. A broader and more massive treatment with shallow mouldings distinguishes it from a limestone Gothic. Sandstones are liable to be obscured by smoke in large cities and are therefore at a disadvantage.

Older than the Trias and Permian and below it, the Carboniferous system of England supplies the sandstones and grits of the north country and the limestones and marbles of Derbyshire. The Carboniferous system takes its name from the coal measures which occur within it. Millstone grit is a hard, durable stone useful for carrying loads. The laminated sandstone, known as York stone, is specially employed for "plates" and bearings for girders. The grit stones give their simple character to the Cistercian churches such as Kirkstall Abbey near Leeds, and Fountains Abbey. The plain stone manor and farm houses of the north country (Fig. 34c), and the hard northern Classic buildings such as the railway station and post-office at Newcastle owe their character to the sandstones and grits of this system. The calciferous sandstone in the neighbourhood of Edinburgh, of which Craigleith stone is the type, occurs in the Carboniferous; its properties, as we have seen (ii. 8), have contributed to the refined Classic of the "new town" in Edinburgh. In the south a Carboniferous sandstone occurs in South Wales of which Tintern Abbey is built.

Carboniferous limestones occur in Derbyshire and in Ireland and give a particular character both to the scenery and to the buildings. In Derbyshire

¹ Both sandstones and grits are formed from the debris of granites. When granitic rocks decompose and their quartz, mica, and felspar ingredients are separated, the quartz debris often tends to sift into different beds; the coarser grains when consolidated become *Grit*, the finer grains become *Sandstone*. (29)



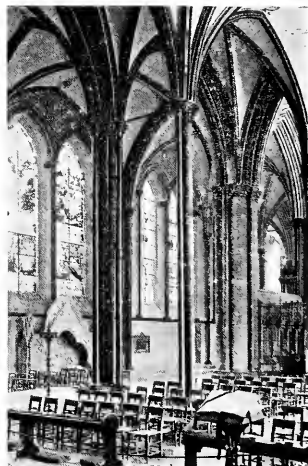
Tertiary—Essex. St Mary Fryering in Brick.



Cretaceous—Norfolk. Diss Church in Flint.



Carboniferous—Yorkshire. Beckett's Park, Leeds.
Sandstone Classic.



Jurassic—Salisbury Cathedral.
Chalkmark Limestone and Purbeck Shafts.

the well-known marble known as Hopton wood is a Carboniferous stone. In Ireland nearly the whole of the central plain is Carboniferous and provides the characteristic grey limestone seen both in Classic and Gothic structures in that country. In Kilkenny, Carboniferous sandstones and marbles occur ; the Abbey of Jerpoint in that county is a Gothic church built in local sandstone.

Older again than the Carboniferous is the Old Red Sandstone which has

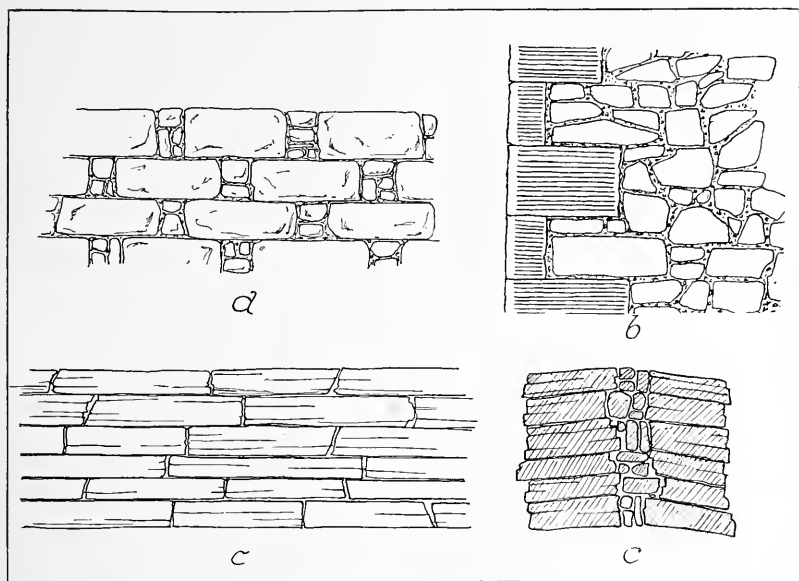


FIG. 34d.—WALLS SHOWING DISTINCTIVE GEOLOGICAL INFLUENCE.

produced many beautiful buildings. It is found on the Welsh borders and in the Forest of Dean and has given its character to the town of Hereford and also to Lichfield Cathedral. In Scotland the rich variety in masonry visible in the Lowlands and in the Border country is due to the reds and browns of the Old Red Sandstone added to the sharper bronzes of the calciferous sandstones. Jedburgh and Melrose abbeys are upon the Upper Old Red Sandstone and are built of it. It will serve as rock-facing, as ashlar, or as rubble ; the core of the piers to the Forth Bridge are in sandstone rubble from Arbroath.

In the west of England the old rocks of the Devonian system supply the fine limestone or "marbles" of Devonshire. The characters of the towns of Plymouth and Torquay are due to Devonian stones of this character.

The volcanic rocks supplying granite are found in England, in Devon and Cornwall, in Leicestershire (Mount Sorel), and in Cumberland and Westmoreland (Shap granite). In Scotland these rocks cover large areas. Wherever they occur they stamp the building of the region. In Cornwall and in many parts of Ireland the chief sources of gray granite are the boulders split and worked upon an antique tradition. Stones of very large size can be obtained from these boulders and many large-lintel buildings from the megalithic monuments onwards in Cornwall and the west of England are of granite.

Nearly the whole of the north of Scotland is igneous and granites occur in many places. The famous Peterhead quarries north of Aberdeen supply a pink granite which is treated almost as a precious stone; it is quarried, polished, and carried to all parts of the British Isles. The town of Aberdeen is built of and upon gray granite, the most famous quarry being Rubislaw whence stone was had for building the Bell Rock Lighthouse. But the quarries in the surrounding districts produce stones of a considerable variety in colour. A beautiful Aberdeen granite, in colour gray, weathering to brown, was conveyed by water and used for the facing of all the piers to the Forth Bridge.¹

In Fig. 34*d* three walls are illustrated showing distinctive geological influence:—a checker work of squared sandstone and dark rubble *a* near Edinburgh; quoins of old-red sandstone with grit and basalt rubble *b* common in the Border country; wall of Cumberland shale laid with sloping beds *c*.

9. CONCLUSIONS TO BE DRAWN

Inventive designers can twist and compel a material to serve them and to take up the shapes they desire. But the finest forms in architecture are those in which there is an obvious link between the form and the material. Thus the beautiful and appropriate lintel forms occur in countries such as Greece and Egypt, rich in marbles and crystalline stones of long dimensions (iii. 1 and 2). Thus the fully-developed Gothic forms (iii. 7) have risen from the long limestone "bancs" of Burgundy and the Paris basin. The dome seems to be at its best

¹ "The granite was brought, roughly dressed and squared, in specified courses ranging from 21 ins. in thickness down to 16 ins., and also specified as headers and stretchers so as to form proper bond with the hearting of rubble masonry or concrete." (W. Westhofen, *The Forth Bridge, Engineering*, Feb. 28th, 1890.)

where bricks are traditional. At Constantinople, a pozzolana tradition from Rome meets a dome form tradition from the East and we find as a result the great Church of St Sophia. Constantinople with its brick earths and limestones in equal accessibility and with its marble island of Proconnesus at hand had the material in itself for its characteristic building shapes. On the other hand dome forms in masonry countries as Armenia and Angoulême in France tend to revert to the corbel or develop into the pointed arch.

It is proved again and again in history that harmony rather than conflict in material makes for great design, and where a rich variety of materials exists there the most beautiful and enduring traditions take their rise. This is best illustrated by the coinciding of three fertile building materials—brick-earths, travertine limestone, and pozzolana cement—upon the Roman Campagna.

To-day the great common fact in material before the architect is the large bending strength of steel and of reinforced-concrete lintels. This fact conditions his design exactly as the small bending strength of masonry lintels conditioned the lintel construction of the Greeks and the homogeneous joint, due to pozzolana, conditioned the building of Roman vaults. Where large common structures are concerned this age is again a lintel age. Now early lintel construction in masonry occurred in countries having the finest crystalline materials and as a result of this we shall see that the whole building tended to be sculptured into a smooth, jointless whole as though in one piece (iv. 5). But this "monolithic" or joinery technique was, as we shall see (v. 5), superseded by the Romans owing to the immense scenic effect of travertine in large blocks rusticated or channelled. Roman travertine, and Florentine macigno, caused by their special qualities the development and emphasis of the rusticated or "many-stone" wall treatment with its voussours or arch stones and with its enormous blocks projecting as much as two feet from the plane of the joints. This treatment—an emphasis on mass—the result of travertine and macigno must be clearly distinguished from the smooth, jointless treatment of granite, marbles, and plaster surfaces by the earlier Egyptians and Greeks. The "travertine" is an embodiment of distributed load and is well emphasised by ruggedness and multiplicity. The latter—the smooth monolithic—is essentially a joinery, whether in stone, or in timber with a plaster skin.

To-day, for obvious reasons, the more ancient monolithic or joinery treatment applies with greater sense and art to the modern steel-frame building which should look what it is, namely all of a piece, and cannot bear over emphasis upon a mass which does not exist. Also the Greek colonnade structure—that is to say the concentration of loads upon points and the careful expression of those points

III. 9. Theory and Elements of Architecture

by columns with vertical flutes—has a direct bearing upon the modern design of shop fronts. But this does not mean that the massive wall can be neglected. The grand masonry traditions of Rome and Florence are still fruitful because massive masonry has still its uses and its applications. But the essential distinction between the two should be constantly borne in mind. We shall in the next chapter consider more minutely the various methods of wall construction.

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MILAN. SFORZA CASTLE.

[H. B.]

Chapter IV

WALLS AND WALL SURFACES

1. *MASS AND SURFACE*

THE wall, both as a mass presented to the eye, and as support and screen serving useful purposes, is the first element in building.

A vast wall is impressive in itself. The retaining walls of Mesopotamia (Fig. 44), the wall of the Forum of Augustus at Rome (Fig. 57) devoid of any incident but the jointing of the material, or a medieval wall such as the exterior of the palace of the popes at Avignon,¹ or at the Sforza Castle, Milan (shown in the headpiece to this chapter), may by mass alone convey an overpowering impression to the mind. The impression caused by mass is one of the first facts in architecture and can be used skilfully or otherwise. Also the surface alone can please the eye because various cut minerals have a character and beauty of their own. An expanse of flint or brickwork or the shades and texture of fine masonry (Figs. 18 and 74) can give a satisfaction which cannot be referred to utility.

2. *SUPPORT AND SCREEN*

The wall has two prime uses—it both protects from climate and supports the weight of the roof. As a support it can either be continuous or broken up into sections at positions best suited for supporting the load or for picking up the thrust of the roof. When broken up thus it can lose its protective character

¹ See headpiece to ch. x.

altogether and become a series of pillars or piers, or again may take the form of a series of supporting walls or buttresses placed at right angles and connected by thinner screens between. We shall see that these three methods are roughly characteristic of three schools of building (Fig. 35).

An architect in the process of design should consider carefully the degree of emphasis that he will give to the supporting as compared to the protecting part of his wall. If the material of which his wall is constructed is equally capable of supporting weight and of resisting the weather, as is stone or brick, then he can readily merge the expression of the two functions if he wishes to do so, as in the case of the brick front of a Georgian house. But if he must use one material for the first purpose and another for the second then the problem is more difficult (v. 8 and 9).

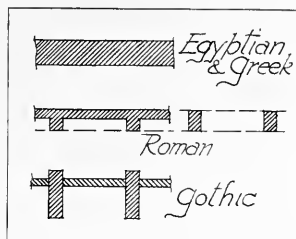


FIG. 35.—WALL PLANS.

3. STABILITY

All walls are subject to over-turning forces of one kind or another. A garden wall five feet high and nine inches thick without cross walls and built in lime mortar can be blown down by a fifty mile an hour gale. (1) Therefore the centre of gravity of a wall should be as low as possible. This was well understood by some of the ancient builders. In Egypt the wall was sloped or "battered" on the outside which lowered the centre of gravity and distributed weight (iv. 7). The Persian builders at Ctesiphon made of the upper part of their wall a hollow boxing—by that means lowering the centre of gravity and increasing stability (Fig. 36). Similar means appear to have been adopted also by the Roman architect who built the great "Poikile" wall, designed to give shade, at Hadrian's villa near Tivoli. A wall without cross-walls requires a considerable area of base. A safe thickness of base is at least one eighth of its height. All walls require a definite relation of thickness to height to ensure stability. Walls in combination with cross walls at right angles to them can afford to be relatively thin in section. But this was not realised by some of the early builders. In Egyptian architecture for instance there are many examples of walls so thick that they could well rest securely on their own base, but built notwithstanding in combination with cross walls (Fig. 37).

Stability of walls involves, therefore, a safe distance between cross walls in addition to a right proportion between base and height. The stability of the

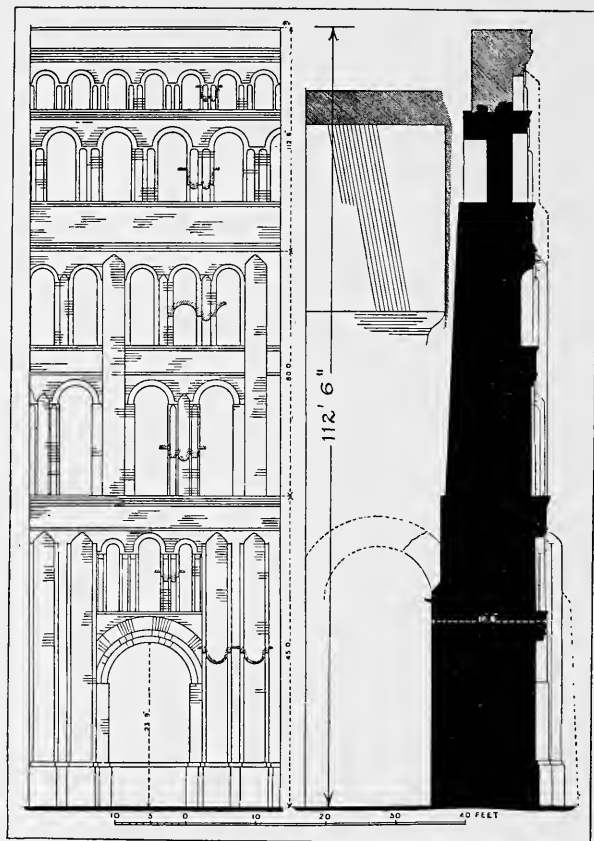


FIG. 36.—CTESIPHON. SECTION OF PALACE FAÇADE. (From Spiers.)

Roman *insula* or apartment house was early a matter of concern in Rome. Augustus limited the height of the fronts of new houses to 70 Roman feet, and a new building act by Trajan fixed the height of the street front at 60

feet.¹ It is thought that behind the street front these *insulae* rose to six or eight floors.

The London building regulations to-day do not allow any wall, in combination with cross walls, to be more than sixteen times its thickness in height. The distance apart of cross walls is also regulated. When greater

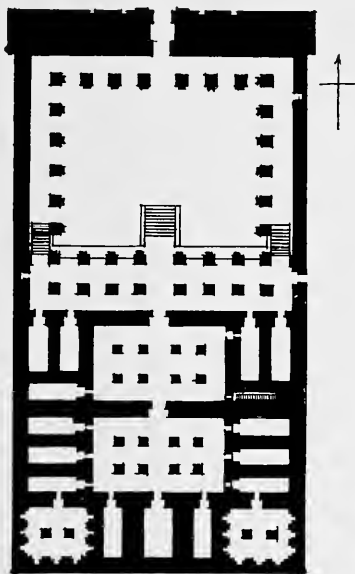


FIG. 37.—ABYDOS. PLAN OF TEMPLE OF RAMESES II. (After Weigall.)

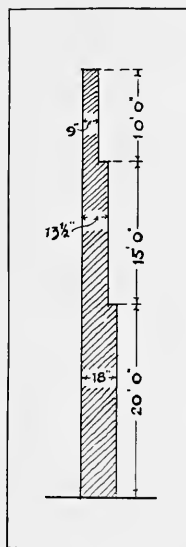


FIG. 38.

heights are required the lower portion must be thickened by $4\frac{1}{2}$ -inch offsets on the inside (Fig. 38). But where special systems of construction are employed it is not uncommon to find walls having a proportion of width to height of 1 in 40 or 50.

When a roof or vault is added upon a wall the wall is subject both to a vertical pressure due to the dead load and also to a horizontal pressure due to thrust. The dead load ensures stability if the foundations are sound. The

¹ Lanciani, R., *Ruins and Excavations of Ancient Rome*, 1897, p. 568.

thrust of the roof or vault tends to overturn. Sheer weight therefore is sometimes an advantage. For instance in St Paul's nave the mass of the aisle wall is purposely increased by the addition of an upper part above the first cornice, apparently ornamental only but in fact filling an important rôle (Fig. 39). It was a common practice in medieval building to weight both buttress and clerestory with heavy pinnacles in order to increase stability (see Fig. 62). The medieval builders were masters in the art of balancing the parts of a building against each other and achieving by that means a highly complex equilibrium, but this method does not make for the great durability characteristic of the simpler methods, and causes extra expenses in the matter of repairs and maintenance.

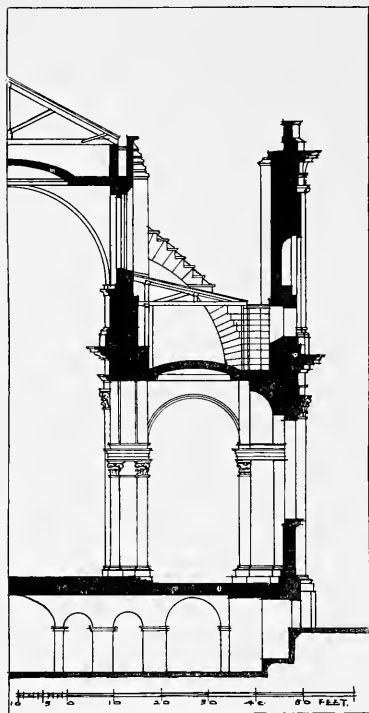


FIG. 39.—LONDON. ST PAUL'S. SECTION OF NAVE.

pressure is concerned. (1) A moderately thick wall is better constructionally than a thin wall with shallow buttresses.

4. STRENGTHS OF MATERIALS

The resistance of a block of stone or of wood to crushing, that is to say to compression, is called its *compressive strength*. The resistance it offers to being pulled apart, that is to say to tension, is called its *tensile strength*. When a loaded

beam is placed between two supports the under side of the beam is offering resistance to tension, the upper side to compression, therefore both compressive and tensile strength must be considered in all buildings in which there is a span between supports, that is to say in nearly every building. But some materials are more suited to resist tension, and some to resist compression.

Let us consider for a moment the relative strengths of materials. The safe compressive strength of good masonry in cement mortar, on a broad average, is 220 lbs. per square inch, but its safe tensile strength is not more than 40 to 50 lbs. per square inch, and as a rule is scarcely taken into account. A marble beam laid as a lintel will have a safe tensile stress of perhaps 50 to 100 lbs. per square inch. The strength of timber, when the stress is along the grain, is much more than that of masonry—as much safely as 1000 lbs. per square inch.¹ A timber beam, unlike a masonry beam, has both compressive and tensile strength approximately equal. The strengths for constructional steel are 16,000 lbs. per square inch both for compression and tension.

The important distinction to be drawn is between materials such as wood and steel which are equally strong against either compression or tension, and materials such as masonry and brickwork whose main strength is against compression only. The constructional nature of these two types has an important bearing on design. Very roughly, the historical progress of building appears to be from timber or wattle-and-daub to irregular masonry or the piling-up of large stones, from irregular masonry to masonry in courses with mortar, and thence, after centuries, to constructional steel having some kind of protection against the weather. A progress, that is to say, from a material having an equality in strengths in tension and compression (timber) to one having a high compressive strength with no tensile (irregular masonry), onwards to one with a tensile slowly increasing with the strength of mortar but never approaching equality with the compressive (the bricks and the regular masonries). Thence to an equality again but at a higher power (constructional steel). Of these stages the first and the last, that is the wood and the steel, resemble each other in their constructional nature and likewise the members of the centre of the series—the bricks and masonries.

Now the building processes connected with timber, namely carpentry, has produced and produces its own type of structures. The post, the panel, the

¹ This high figure refers only to when the stress is in the direction of the grain of the wood. It is considerably less when the stress is across the grain. All the figures for compressive strength given here are assuming "short" columns.

beam, the truss, are characteristic of carpentry and of the architecture produced by carpenters and boat-builders, such as the Scandinavian and the English in medieval times. Very different are the types of structure produced by the mason and the brickbuilders—the great masonry styles such as the Roman and the Florentine have strong characteristics equally distinct from the characteristics of the carpentry styles.

Broadly the distinction is between the *panel* and the *course*.

Turning now to steel, it is obvious that its constructional nature resembles joinery rather than masonry, since we have seen that it has that character of equality between its compressive and tensile strengths. The *panel*, therefore, from a purely logical point of view, should play an important part in any architecture based upon constructional steel (v. 9 and x. 6).

We have so far in our argument ignored the concretes. The development of cement has been always towards greater tensile strength, and the use of this material in the form of arched vaults and domes has run parallel to masonry in many great building periods. Concrete is the use of structural units small enough in size to be easily mixed and surrounded with the cementing material; thus the strength of unit and of joint approaches an equality and as a result the whole mass becomes more plastic. Hence its use for vaults and domes. Owing to equality between joint and unit mud-bricks in a mud mortar have constantly been used to build domes (iii. 5) in the East. The Roman concrete vaults attained huge spans owing to the tensile strength of pozzolanitic mortar (iii. 3), and a part of the vault of the ruined basilica of Constantine for centuries overhung one of its abutments and remained in the air owing to its tensile strength alone.¹ In the nineteenth century it occurred to engineers to strengthen or reinforce the crystalline tensile strength of concrete by artificial means. Rods of iron were introduced in the lower portions of a concrete lintel where the tensile strength is needed. Thus the adequate compressive strength of masonry was combined with the high tensile strength of steel.² Hence arose "reinforced concrete." This was not an innovation in principle. Wood members had early been introduced as reinforcements into mud-brick structures in Cretan and Mycenaean buildings (iv. 10). An old tradition among English bricklayers in some country districts, is to lay straws along the beds in all brick courses immediately above window and door heads. The practical results in modern building of reinforcing concrete is to produce a structural material, non-homogeneous, but much more a carpentry than a masonry. Structurally, therefore, the tend-

¹ It has now been secured by iron straps.

² See also vi. 11 p. 227.

ency of modern reinforced concrete building should also be towards the panel rather than the course.

But architecture has never been purely structural. It has been structural plus a whole range of other factors. It must be recognised that wood and wattle forms were for long imitated in masonry because they were familiar and beloved, and that, for the same reason, masonry columns have been applied at all periods as decoration to concrete walls. To-day steel structures are made to conform to a masonry tradition because among other and less admirable reasons, its shapes are decent and familiar. Is it right or wrong that there should be this overlapping and survival of forms after their true reason for existing has disappeared? The student must think out this problem for himself; the phenomenon is not confined to architecture. Clear thinking upon *facts* will lead him to new and truer *forms* which, in their turn—if they are beautiful—will become familiar. But let him begin by being certain of one thing, namely, that whatever forms he uses he shall know their meaning and implication.

5. EGYPTIAN USE OF STONE

In the history of structure we are confronted at the outset with the strange fact that the “common sense” treatment of a stone wall, namely, as a superimposed series of “courses” showing the joints between stone and stone was not arrived at for many centuries. The ancient Egyptian stone wall was intended to look jointless. It was of great thickness, the joints were reduced to the minimum possible both in number and size, and it is obvious from the examples remaining, that the builders intended the whole to look as if constructed not out of many stones but out of one large stone, in other words to look “monolithic.”

The illustration given (Fig. 40), of the pylons of the Egyptian Temple of Edfu, is an example of monolithic structure. The building is in fact a copy in stone of clay or mud-brick forms. The decoration is applied over the whole wall regardless of the stone jointing. This apparently illogical imitating of a clay structure in the hardest stone, can be explained only by reference to the object in view in Egyptian stone building.

The use by Egyptians, of the old kingdom and onwards, of stone for tombs and temples was first for the sake of its durability; because by its means they could make endure for all time the forms they already knew and delighted in in ordinary life—forms not only ancestral but also contemporary. (2)

The mud of the Nile and the African sun together furnished bricks as easily and indolently as flowers and crops (ii. 1). The house and the garden were

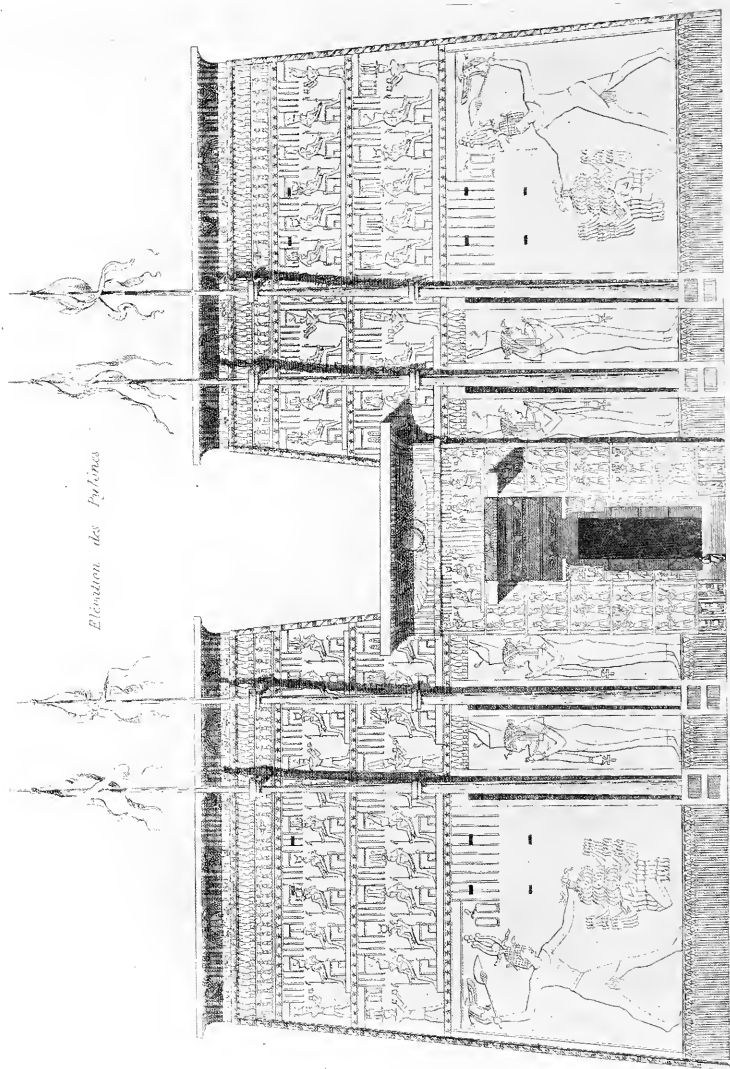


FIG. 40.—PYLONS OF TEMPLE AT EDFU. (4 Restoration from Gaillabaud's Monuments.)

almost natural products. So rich was life to the ancient Egyptians that by common consent it was worth while using all means in order, after death, to be reminded of it for eternity. The *ka* or eternal part of a man was conceived of not as a "spirit" but as an almost physical "person" requiring the continuance of the material conditions it knew. The tomb, the "eternal house" as its name signifies, with its engraved walls, its furniture and personalia was the home of the *ka*. The two together constitute an unphilosophical attempt at prolonging the bright interval of life. The means of prolonging and conserving material conditions was at hand in the quarries of Turra, Duchan, and Syene. The resistance to time of black basalt and red granite rather than the decorative value of these materials caused them to be employed in building.¹

The Egyptian tomb or temple was not so much built in masonry as crystallised or sculptured into an imperishable from a perishable material. An understanding of this attempt to make eternal the familiar—of this salvation by masonry—is necessary to an understanding of Egyptian architecture and of its derivatives, that is, to an understanding of the monumental idea in architecture. In early times "the monumental" and "the monolithic" were the same.

6. FIRMNESS IN EGYPTIAN WALLING

The wall plays the major part in Egyptian architecture. Since rain was almost unknown in Egypt (ii. 1) the roof as an element remained flat and unformative. Yet masonry as fine ashlar, seems not to have occurred to the ancient Egyptians, in spite of the fact that mortar was known and used. Mortar is found about a fiftieth of an inch in thickness in the joints of the pyramid of Khufu evenly spread in the most skilful manner. But weight rather than mortar, was looked upon as the primary instrument of adhesion. Public monuments were called "Firm Things," things not to be shaken. This idea of *Firmness*, of lasting for ever—which we have already seen was part of the monolithic idea—was in early times the aim and object of all architecture. "Truth and Justice were qualities much sought for (by the Egyptians) in life and were expressed by the artist in the reality of his immense blocks of stone, often more hidden than seen, and in the fair and even bearing of all material without any tricks or paradoxes of structure. In all his earlier work his monolith columns and pillars were a protest that a structural unit must express unity and that what supports others must not be in itself divided." (3)

¹ See *Appendix, Note 3* for a fuller discussion of this point.

7. SLOPING OF EGYPTIAN WALLS

The Egyptian builders with these ideals before them, came to possess considerable knowledge of the principles involved in the carrying of great loads.

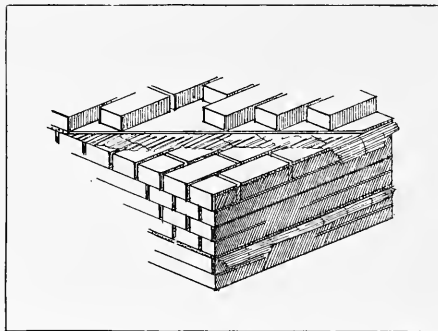


FIG. 41.—EGYPTIAN WALL IN BRICK WITH BONDING MATS OF ALFA GRASS. (After Choisy.)

The advantage of the pyramid shape is that at any level it provides a relatively large bearing area for the load to be carried. All walls in thickness should logically decrease upwards as the load decreases. To-day we decrease them by "set offs" (Fig. 38). The Egyptians actually shaped the stones. Owing to the softness of the soil in Egypt this principle applied specially to foundations. The ground supporting the buildings was an alluvial soil flooded every year and thus alter-

nating between soft mud and hard cracked clay. Extremes of temperature

between night and day¹ also made for expansion and contraction and thus for the disintegration of walls. Earthquakes had also to be encountered. The problem was to ensure stability and allow for movement—a problem which has still to be met in modern times by Egyptian builders. (4) The Egyptians laid their mud bricks in curved or sagged courses; they had only an elementary knowledge of the principle of bonding, and used alfa grass in the beds (Fig. 41). (5)

The curving of the courses (Fig. 42) had the following effect—movements due

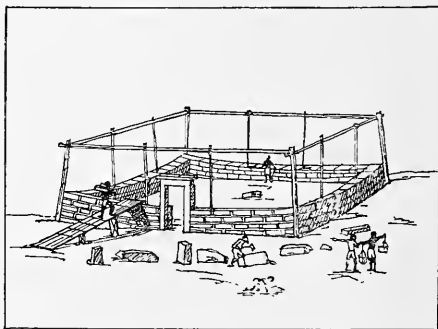


FIG. 42.—THE BUILDING OF AN ANCIENT EGYPTIAN HOUSE. (After Viollet-le-Duc.)

¹ "Experiments have shown that the range of temperature in the middle of a wall, three-quarters of a metre thick, in Cairo, may be 40° F. throughout the year." (4)

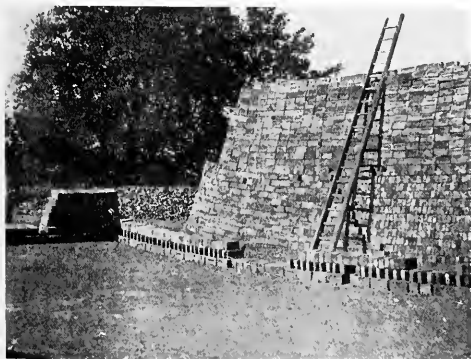
to expansion and contraction tended to throw weight inwards and to solidify the total structure. The result on shape was to give a slope or batter to the outside surface. By this means both strength and the appearance of strength were arrived at. The mortar made of mud and desert sand acted also as a cushioning to distribute load. When the bricks were supplanted by stone courses and greater loads had to be carried, the advantage of these principles in securing stability was greater. This tendency to movement, owing to the soil and the climate, gave rise, in large buildings,



FIG. 43.—EGYPTIAN CURVED COURSES AT PHILE.
(From Choisy.)

to the elaborate masonry course having a wave form (5)—as at Phile (Fig 43).

The modern counterpart of Egyptian walling can be seen in the common brick “clamp.” The bricks in clamps have to be massed together without bond and without mortar, and stability is secured by tilting up the end courses and thereby sloping back the sides (Fig. 43a).



[H. B.]

FIG. 43a.—MODERN BRICK CLAMP BUILT WITHOUT BOND,
AND THEREFORE CURVED AND BATTERED.

8. RETAINING WALLS OF MESOPOTAMIA

We have seen that owing to the lack of stone, bricks in Mesopotamia came to have a special value and in Babylonian times a god of their own (iii. 5). In Mesopotamia, as in Egypt, the alluvial soil recurrently inundated, set an initial problem at the foundations. Only by the distribution of weight over large areas could

IV. 8. Theory and Elements of Architecture

the loads be carried. We find also the immensely thick walls, the diminishing of the bearing area with the height giving a sloped or battered outer surface, and only a slight recognition of the principle of bonding. The Mesopotamian builders, had no such stone resources as Egypt, and did not imitate their clay structures in stone as did the Egyptians, but they carried to a high development



[By permission of Trustees of British Museum & University Museum, Philadelphia.]

FIG. 44.—UR. SOUTH-WEST FACE OF ZIGGURAT.

the principle of the brick retaining wall set in bitumen mortar.¹ These retaining walls gave stability and shape to huge spoil heaps of crude brick or clay, the supply of which was probably connected with the excavation of their canals.² The

¹ Bitumen mortar is a natural asphalt mixed with earth. See p. 66.

² Mr C. L. Woolley, head of the Joint Expedition of the British Museum and the Museum of the University of Pennsylvania to Mesopotamia, writes on this point as follows:—"As regards the source of the material this is not yet proved but (a) there were canals passing close to the city (of Ur), and (b) judging from a large low-lying area in the ruins, there may well have been an artificial dock within

ziggurat, the palace, the fortress, rose above the flooded country like small mountains, and these mountains supported indeed a series of civilisations. Access to the artificial heights from the plain gave rise to the fine ramps and stairways which are characteristic of Sumerian, Babylonian, and Assyrian buildings.

Vast sub-structures such as the retaining walls of the ziggurat at Ur, present the idea of sheer wall in a marvellous manner (Fig. 44). The outer wall of burnt brick set in a bitumen mortar retains the inner core made of unburnt brick in mud mortar. (6) Scale is given by the number of weep holes or small openings left for the purpose of draining the clay core. The half-brick was known and used for bonding, "but as most bricks were approximately square, internal bonding is bad; the total thickness of the wall is made up of a series of skins with little or no structural cohesion between them. To meet this weakness the builders put layers of reed matting in the bitumen mortar between the courses—the mats running right through the wall served the same purpose as the wire netting occasionally employed in modern 'reinforced brickwork.'"¹

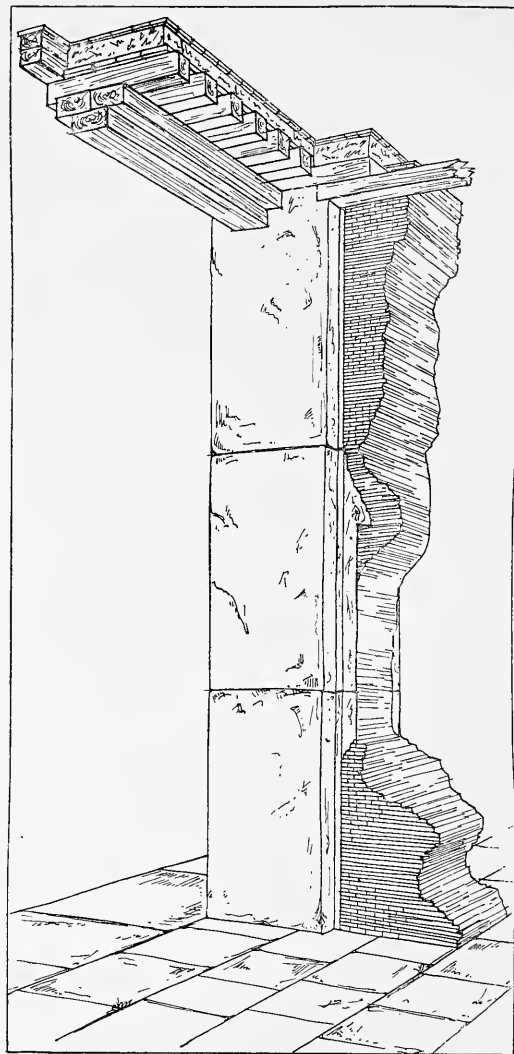
The painting and decorating of the walls of houses and palaces in bright colours was common. Coloured tiles and coloured bricks were used (Fig. 75*a*), later in Assyrian times large blocks of alabaster conveyed down the Tigris from the Taurus hills (iii. 5), served both as revetments to retain the walls of crude clay and as slabs for records and sculptures. Assyrian sculptures, even when partly detached from their walls, retain their narrow slab character as illustrated in Fig. 44*a*.



FIG. 44*a*.—PALACE OF ASSUR-NASIR-PAL, LION, SHOWING SLAB CHARACTER OF ASSYRIAN SCULPTURE.

the city walls close to the Temenos and the ziggurat, and the spoil from this would have supplied plenty of brick clay." See also Herodotus' description of Babylon, "As they dug the moat they made bricks of the earth." (Herodotus, i., 178.)

¹ Letter from Mr C. L. Woolley.



9. PERSIAN WALLS OF TWO MATERIALS

The mud-builders of Mesopotamia had stone-builders on their east and west (iii. 5). On the west the Hittites used large stones to form supporting or plinth walls upon which to build a wooden and mud-brick superstructure. In the east the Persians at an early period used the grey limestone of their mountains to build fine masonry walls to their large platforms. The Persian platforms at Persepolis (of the Achaemenid period) were built of very large stones laid dry, relying upon weight for adhesion. These stones were not plastered over but were meant to be displayed and admired and in some cases seem to have been "rusticated" (v. 5). But the special contribution of the early Persians in wall building was a scientific combination of mud-brick and stone. The mud-brick and stone buildings rested upon the masonry platforms. At Persepolis an angle pier (Fig. 45.) of the

FIG. 45.—PERSEPOLIS. PERSIAN STONE PIER AND MUD-BRICK PANELLING. (After Dieulafoy.)

Palace of Xerxes has alternate openings to receive the toothing of the mud wall exactly as a modern pier might be constructed to receive a concrete panel and avoid a straight joint. The frames for doors and windows were constructed in stone and the mud-bricks formed screen walls, probably plastered over, between the stones. (7) At Persepolis to-day the stone doorways, windows, and angle pier are standing detached—the mud - screen walls having crumbled between them. We shall see later that this method of construction by piers and panels has a special application in modern design (v. 9).

10. ÆGEAN WALLS

To sum up the preceding sections: builders in ancient Egyptian and Asiatic lands used mud-brick for every purpose and frequently plastered and coloured it; but where stone was available they used it as a platform or base, and where it was copious (as in Egypt) they used it for imitating or translating the mud-brick forms into masonry. All these tendencies came westward and northward and found re-inforcement in various requirements and materials. We have already analysed the materials of Greece as those of a limestone peninsular converted into marbles over large areas. But behind the marble civilisation of Classic Greece there existed a long complex tradition.

Round the Ægean Sea early conditions of life were very different to those of the great river valleys of Egypt or Mesopotamia. Frequent islands occurring between Asia and Europe induced both piracy and sea-borne commerce, and at the same time the mountains of the main land with their spur-hills provided ready fortresses. Hence we find the acropolis hill or citadel at Mycene, Argos, and Athens, sufficiently far inland to avoid pirates,¹ and surrounded by good stone for the building of walls. The steep mountain valleys tended to keep tribes



[H. B.]
FIG. 45a.—KNOSSOS. RECONSTITUTION BY SIR ARTHUR EVANS OF PART OF THE UPPER PORTION OF THE PALACE.

¹ Thucidides, *History of the Peloponnesian War*. (Opening paragraphs on the early settlement of Greece.)

IV. 10. Theory and Elements of Architecture

apart and develop their talents, while the extensive inlets of the sea led to ship-building and provided a means of travel or of easy migration. The climate was temperate and sparkling and though protection against rain was necessary, neither of the severe extremes (iii. 5) common to Asiatic lands had to be encountered.

The first Ægean civilisation, that of Crete, was founded on sea power, and



[B. C. A.]

FIG. 45*b*.—KNOSSOS. PALACE OF MINOS. STAIRCASE AND LIGHT WELL.

its cities, unlike any upon the main land were without defensive walls. But Knossos is some three miles from the coast. Knossos was the first of many flourishing cities in which building progressed for fourteen hundred years contemporary with a large part of Egyptian history. Crete, unlike the main land and Cyclades, is without marble but has excellent limestone, brick-earths, gypsum for slabs, and a natural clay cement still used for roofs on the island. In Minoan¹ times the timber was plentiful. The building technique is essentially a heavy "half-timber" work in cypress wood set upon a stone plinth (Fig. 45*a*), and filled in with rubble or mud-brick, plastered over. Floors and roofs were of heavy

timbers, and wide timber spans were supported by a centre column that

tapered downwards (Fig. 45*b*.) The necessity of building retaining walls for terraces in exposed positions—as the east bastion at Knossos—led by stages to the finest regular coursed limestone masonry in a lime mortar. There is evidence from the faïence tablets and models of shrines (8) that sometimes the joints of stones were channelled or emphasised so that each stone was noticeable as a structural unit (p. 140), but generally walls were plastered over and probably coloured. Thus

¹ The term Minoan—from Minos the priest-king, who is said to have built the great palace at Knossos—is applied to culture under Cretan domination, it is divided into three periods and known as Minoan I., II., and III., and each period is further sub-divided into three.

a masonry technique and a timber technique coincided. Timber was also used as bond-pieces through the thickness of all Ægean walls (Fig. 46). Long timbers for bonding are useful in masonry against earthquakes and have been found in Egyptian structures (4); the practice is followed in the Near East to-day. Walls were also formed by double slabs made of gypsum stiffened by wooden "ties" (Fig. 47) and having rubble between them. Roofs and drains were coated with the native clay cement. No fireplaces or flues existed in Minoan times nor do they exist to-day in Cretan houses. This enabled rooms to be placed one above the other—a step in domestic planning not adopted on the main land for centuries—and led to Minoan light-wells, staircases (Fig. 45*b*), and windows (Fig. 145) of a modern appearance. (8) Minoan sanitary conditions also were excellent and they made the important contribution of true partition walls; these were of thin gypsum slabs laid in a clay mortar.

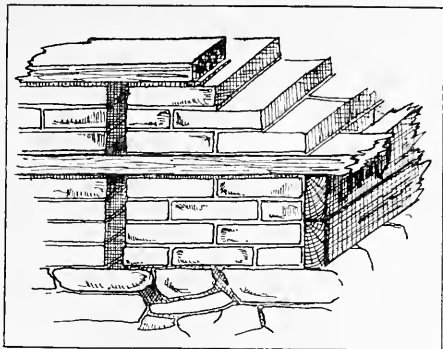


FIG. 46.—ÆGEAN WALL, HAVING BONDING TIMBERS.
(After Durm.)

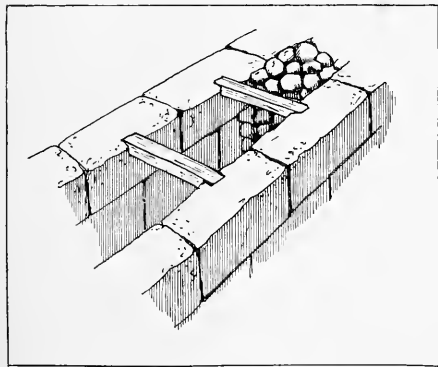


FIG. 47.—WOODEN TIES IN A MINOAN WALL.

Even before the destruction of Knossos (about 1400 B.C.) the centre of culture seems already to have shifted to the main land. Tiryns, Argos, and Mycene, along the Argive plain had derived much but by no means all from Crete. The hills around the Argive plain yield (i) a hard close limestone having inclined beds and considerable cleavage which gives large irregular stones; these were used by the

IV. 10. Theory and Elements of Architecture

builders for their acropolis walls; and (ii) a conglomerate. The large beehive tombs at Mycene are carved out of the conglomerate rock. It gave large rectangular blocks used by Mycenean builders for sills and lintels (Fig. 16a) but must have been hard to work with bronze tools, and comes to a blunt edge or arris. The Argive builders used this conglomerate for facing



FIG. 48.—MYCENE. (*After a Restoration by Charles Chipiez.*)

and retaining their beehive tombs (iii. 2) and appear to have imitated in this material the regular coursed masonry of the Cretans. But the large irregular or polygonal masonry of the acropolis walls of Tiryns and Mycene has no prototype at Knossos; it is of great size and must have required great skill in erecting owing to the enormous weights of unit stones. These walls improved and strengthened the natural rock chosen as acropolis or citadel. The quarrels and alliances of

the early city states each clustered upon and about its own acropolis, the disorders of their royal families, their songs and sieges are transmitted to us by Homer. The acropolis walls made possible so internecine a civilisation; walls indeed have played an important part in the history of Greek states in all periods.¹

The Mycenaean walls were planned to assist the defence of the city in a special manner; the entrance could only be reached by attackers exposing their right or unshielded flank to persons on the walls. (9) Brick battlements were added along the top (Fig. 48). This kind of walling is immensely impressive when seen to-day. It seized the imagination of later Greeks who gave it the appropriate name of "Cyclopean."²

The same inclined strata with many cleavages exists in the hills around Athens and the old citadel wall of Athens known as the Pelasgic wall was "Cyclopean" in character. Polygonal walling means a readiness in quarrying but means considerable skill in piling up and fitting



[H. B.]

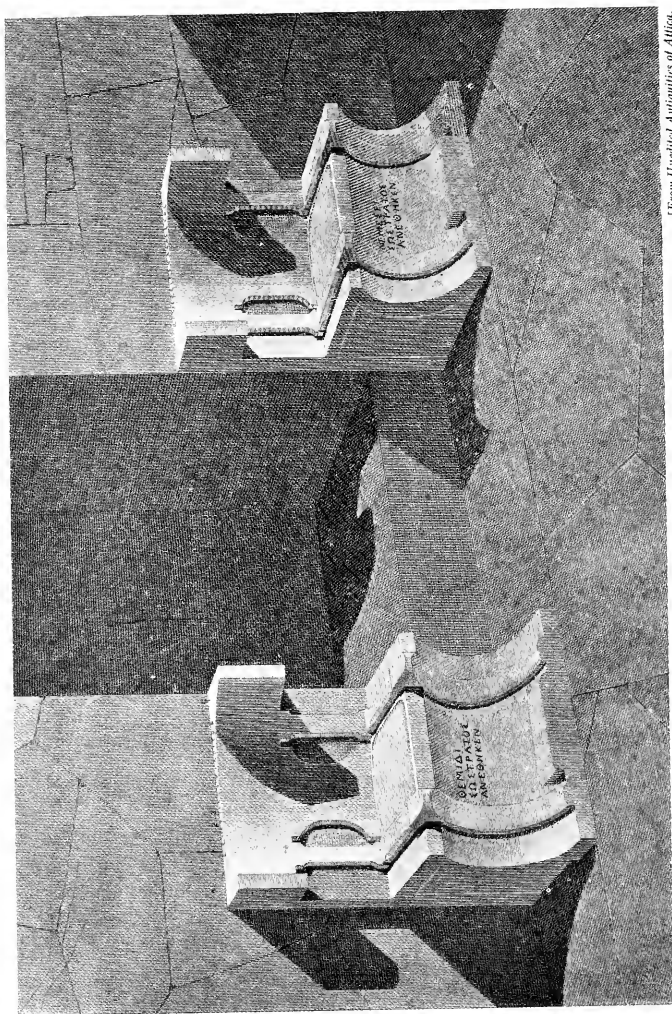
FIG. 49.—ATHENS. POLYGONAL BASE IN A MODERN GREEK BUILDING.

together. Small unit polygonal masonry has remained a tradition in Greece ever since (Fig. 49), owing probably to the geology (iii. 2); it was not plastered over but intended to be seen and admired. This in Classic times is reflected in the term *Harmonia* used by Pausanias to express the fitting together or fine jointing³ of the temple masonry of the Hellenic period. The polygonal masonry of the cella wall in the temple of Themis at Rhamnus (Fig. 50) well illustrates this *harmonia*. The stones are of marble and the polygons exactly

¹ As an instance Bury remarks that the claim of Miltiades to immortal fame was that he carried the decree by which the Athenians marched out of Athens and attacked the Persians on the plain of Marathon—but "if the tyrants had not pulled down the city walls it (the decree) would assuredly never have been carried." (*History of Greece*, 1900, p. 250.)

² Pausanias, Book II., ch. xxv., "Walls of Tiryns."

³ The Greek term can mean either harmony in music or the fitting together of stones.



[From *Unclassical Antiquities of Attica*.

FIG. 50.—POLYGONAL MARBLE MASONRY, TEMPLE OF THEMIS AT RHIANUS.

fitted; the surface is not plastered but highly polished. (10) But the general use of polygonal masonry was, and is, as a base for something smoother and brighter above it.

The "Cyclopeian" walls of the early acropolis supported the palace of the king. Schliemann first revealed the plans of Mycene and Tiryns and proclaimed them the true Homeric house. The principal building was the megaron, or hall of the king (Fig. 90*a*), having columns of cypress wood in front (against one of which Telemachus leaned his spear¹); having a vestibule within the entrance and a large chamber beyond with a central hearth and four wooden columns surrounding it. This megaron—or else its central portion supported on the four posts—was probably loftier than the buildings which clustered round it, and corresponds to Homer's "high-roofed hall."² The craft of the smith seems to have been highly developed and was applied to structures; walls were frequently covered with metal sheets, as in the description of the House of Alcinous³ and, as the fragments show, in the Treasury of Atreus at Mycene. In Homer references to texture and surface brightness are constantly recurring; the presence of the craftsman and the sense of pride in craftsmanship fills the narrative. The necessity of collecting rain-water in "thirsty Argos" probably caused the roofs to be slightly pitched or gabled (vi. 7).

The walls of the palace within the acropolis were of masonry bonded with timber forming a base; then above the base were sun-dried bricks or rubble having wood bond pieces like the Minoan, and retained at openings and ends of walls by timber uprights. These uprights are important; they are the origin of the Greek anta, and were caused by the nature of rubble or mud walling. The anta not only gave a bearing for the lintel over an opening but also served to retain the walls on either side of the opening; anta and jamb for openings were the same, and in Greek building no difference in design existed between them (compare Figs. 16*c*, 50*c*, and 135*b*). The Greek anta always retained a structural link and differs therein from the Roman appliqué pilaster.

These walls were then plastered over with clay, or lime plaster, and probably coloured. This treatment of walls which concealed all joints and presented a smooth bright surface to the eye, was common, as we have seen, in early times in Mesopotamia and in Crete and was connected with the use of mud-bricks and rubble which required a plaster skin. But it is of special importance

¹ *Odyssey*, xvii. 29, Butcher and Lang, p. 276.

² *Odyssey*, Butcher and Lang, pp. 77 and 79. See also note on "The House of Odysseus," p. 422.

³ *Odyssey*, vii. 37, Butcher and Lang, p. 105.

IV. II. Theory and Elements of Architecture

because, where surface is concerned, it reinforces the "monolithic" idea which we first examined in the case of Egyptian masonry (iv. 5). This monolithic idea was that the building was to be built in stone for the sake of durability but was to look a single jointless whole rather than built of a number of unit stones. But this was a different kind of design to that of the squared or polygonal masonry which we have just considered; the one has also a different kind of beauty to the other. The monolithic suggests brilliance, applied colour, and pattern—it suggests the wall as a field for inscriptions or moulded figures; the many-stone masonry on the other hand relies on sheer mass and multiplicity—the simplest architectural instruments—and on the beauty of texture possessed by many cut stones. These two tendencies in design existed side by side in early Greece. We have seen that the polygonal continued and became a strong tradition. The Hellenic Greeks also carried the monolithic to a pitch of perfection unsurpassed.

II. GREEK MONOLITHIC

At or about the year 1200 B.C. the Mycenaean and Cretan civilisations were finally submerged by the migrations southwards in successive waves of strong northern tribes. Of these the last and most notable were the Dorians, and the final stage of submerging is generally called the Dorian invasion. An obscure process of fusing and interchanging of localities, between settlers and natives, occurred continuously, and by the time history has emerged from legends there has already settled down on the sites of the older communities a new race, compounded of Nordic and Mediterranean elements, and exhibiting that special talent for life called *the Greek*. The Dorians brought with them iron weapons and instruments, but there was something new and penetrative in their minds as well as in their hands. They probably had crafts of their own, but they did not destroy the rich craftsmanship and habit of ornament of the older race, evidence of which we have noted in Homer. Instead they admired, absorbed, and developed it. Thus behind Greek architecture there continues to be a background of fine craftsmanship.

The new mixture of races was as internecine as its predecessors; the acropolis wall played as important a rôle as ever. But it now protects and supports the temple of a god. The temple or home of the god has succeeded in importance the palace or home of the priest-king. This is important in architecture because the home of the god tends to become an isolated single building rather than a "high-roofed hall" like the megaron, with lesser buildings clustering round

it. The transition is discussed in the section on roof design (vi. 8). In Homer we read of Athene returning to the "good house of Erechtheus"¹ at Athens, and the building on the acropolis known as the Erechtheion still bears the name of the mythical king who gave hospitality to the goddess. Now the Greeks were the first people to take as the highest form in which to express their ideas of the gods, the perfected human body. The sculptors of Egypt and of Mesopotamia represented many of their more important divinities with the heads of animals, birds or reptiles, and though this tendency is not absent in Greece—the main current of development is towards a god that is an idealised human type. But this humanism worked in architecture side by side with sculpture; the ideal home or shrine was necessary for the ideal type-man. Beauty in the sense of perfection of form, of an athletic mastery, became a deliberate ideal. Demeter, Apollo, and Athene, were more than embodiments of the natural forces to which human life reacts, they became also ideas of human completeness. Hence the enduring quality of Greek mythology. Human beings cannot escape from the gods of Greece but return to them periodically, and builders cannot escape from the temples or homes of those gods and the shapes they have produced.

We have seen that mud-brick or rubble plastered over, with timber retaining posts or antæ, and timber sills and lintels—the whole set upon a masonry plinth—was the common structure in the ancient megaron. This structure was used by the Greeks for temples as well as for houses. In the temple of Hera at Olympia—the earliest "peripteral" temple (that is temple surrounded by columns)—exactly this construction was employed. Timber columns inside and outside (later replaced by stone), carried the weight, and the clay walls of the cella were only partition walls and were retained and stopped by wooden antæ; these walls were plastered and painted. The masonry plinth upon which they rested can still be seen (Fig. 50a). This kind of construction can be seen in essence in all parts of Greece to this day; it is a common traditional method. For the sake of durability rather than for any other reason this structure was superseded at Olympia, two centuries later, by the Zeus temple in which Poros stone was used throughout except for purposes of sculpture. Here we see the Greeks doing what the Egyptians were doing (iv. 5), namely translating wood and clay forms into stone, not for appearance but for the sake of durability. The monolithic method in both cases had this purpose in view. We have seen that Poros stone was a rough stone giving a good key for plaster (iii. 2), and in fact walls and columns were almost invariably plastered over. Thus joints were entirely concealed and

¹ *Odyssey*, Butcher and Lang, p. 105.

IV. II. Theory and Elements of Architecture

the traditional smooth bright surface, colour-washed and picked out with patterns, was maintained and improved. The cella wall transposed into stone could now carry weight but the timber tradition seen in the Mycenaean structure was carried on in stone forms, and the anta (or retaining post) and the timber beams or triglyphs in the entablature transposed into stone, became part of the developed Doric Order.

The timber tradition indeed was so strong that the Greek builders always preserved the post and lintel method of spanning openings, and of roofing in-



FIG. 50a.—OLYMPIA. PLINTH WALL OF THE HERA TEMPLE. [S. R. P.]

teriors: "far from exceeding the boldness of Mycenaean architecture, or from experimenting like the Acarnanians, the art of Hellas allowed the principle of the dome to pass into oblivion, discarded the vault and adhered almost exclusively to combinations of post and lintel." (11) In practice this can be explained by the fact that Poros or Pentelic marble lintels would give spans up to twelve or fifteen feet—if carefully engineered—which was sufficient for the passage of a chariot in a procession, and that timber for roof beams (vi. 7) was plentiful until the deforestation period.

But this limitation in the matter of structure had far-reaching effects artistically. It tended to confine Greek building art to the exploring and refining of monolithic design. It is necessary to get a clear idea of what was the *appearance*

of the common Greek building which as we said embodied and still embodies monolithic or jointless design in the rough (Fig. 5*a*). It is not a cold, gray architecture such as limestone "Classic" in the north would lead us to suppose; on the contrary it is warm, gay and bright. We have said that all joints were concealed and that the surface was colour washed and picked out with pattern. The soil of Greece produces ochres, red oxides, and other earths which are still used by local builders for lime washing friezes and staining antefixæ or tile-ends. In the Greek climate colours will last in the open air for a century. The ochre wall, the gray or blue frieze, and the red antefixæ are the oldest and most natural of traditions. The brilliant reflected light (ii. 3) enhances, on walls and colonnades, both colours and tones. Another factor contributes to the character of monolithic design; the sun has always cast upon these walls the most delicate shadows from the peculiar light foliage characteristic of Greek plants. A standard of delicacy in pattern has been set by nature and it has influenced the character of Greek ornament. These then, were the attributes of the Doric temple, and they necessitated a bright plaster surface; the Greek colonial temples of Paestum in Italy, and of the great Sicilian cities,¹ the temples of Zeus at Olympia, and of Zeus at Aegina, were all plastered, some with a marble-dust stucco capable of taking a high polish. But the translation of the monolithic tradition from plastered timber and mud-brick into plastered stone, gave a greater influence to the sculptor. Votive images upon temples was an ancestral tradition, and the original terra-cotta or wooden image could now be of stone or marble. Hence we early find metopes of Parian marble in stone temples as in the temples at Selinus in Sicily. The next step was the exploitation of the Pentelic marble in Attica in order to build *the whole temple in marble*—the sculptors' material. Pentelic marble as we have said is almost pure carbonate of lime (iii. 2). Its surface did not require a plaster; it was smooth for colour, and in addition had the beauty of a precious stone. Its joints could be ground finer than any limestone.

These facts led to a marvellous combination of artistic and structural achievement. Stones were not laid in mortar but were dry jointed and metal cramps were used. The fineness of the joints was rendered possible only by grinding the surfaces until a molecular contact was achieved. After the lapse of centuries

¹ Greek colonists were rivals of the mother country in art as in athletics: "It is necessary to imagine the artificial treatment of the Sicilian Dorians, in the form of a finish or 'slip' to the building; and we find that the builders resorted to stucco of an exceedingly fine and hard character to obtain their ends." (Pierce, S. R., "Colour in Greek Architecture in Sicily," *Archit. Assocn. Journ.*, Feb. 1923.)

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some of these Greek walls have become monolithic in fact as well as in idea. Stuart (12) first noticed that some of the vertical joints of the stylobate of the Parthenon had grown together, and Penrose (13) says that one of the south angle columns, pushed out of its position from above, had retained its rigidity, as though the drums had grown together and the whole column become a monolith.¹ Although built up in drums the monolithic character of the columns was expressed by the vertical lines or "flutes" carved upon them.

In dry masonry a considerable danger existed not generally found in modern buildings. Unless the beds were exactly true, an uneven bearing would cause the slight bending and fracture of stones under load. A cushion of mortar, even as thin as in the Egyptian pyramid at Khufu, distributes the pressure and was doubtless employed by Egyptian builders for that purpose; but where no mortar exists heavy loads can only be supported by exact bearings. In the limestone work of the earlier period the bed joint was dressed throughout, in the later marble period the practice developed of "truing up" sufficient bearing-surface on each stone to take the load and of cutting back the remainder so that it carried no weight. The drums of columns were ground together by rotating them. In our illustration of the flank of the temple of Diana Propylaea at Eleusis (Fig. 50b) some suggestions of this exact marble finish is conveyed. In Fig. 50c—the front of the same temple—the treatment in marble of the antæ or retaining posts (p. 113) can be seen; the columns between are inserted to support the lintel intermediately, and are spoken of as *columns in antis*. Temples of this kind clearly show the structural origins we have been studying.

The translucent texture of Pentelic, weathered now to a kind of golden ivory, must—when new—have been of a dazzling whiteness; it is possible that its surface was washed with ochre, as the ordinary new plaster surfaces are washed to-day. This would have tempered the glare. Or it may have been waxed as marble statuary was waxed. The colour generally was applied to surfaces that in secular buildings had always been coloured. In the case of the Erechtheion the ordinary colour-wash found on the frieze of a common Greek house finds its counterpart in the (now faded) black Eleusinian marble. The two are shown side by side in Fig. 50d. Also the marble texture gave an even finer field for the tracing of delicate patterns.

In addition to questions of surface, the marble influenced pure shape. Some

¹ Penrose also suggests that joints in "absolute contact," such as in the best Greek work, would not require the infiltration of rain to make them crystallise together, even supposing it possible that rain could penetrate so fine a joint.

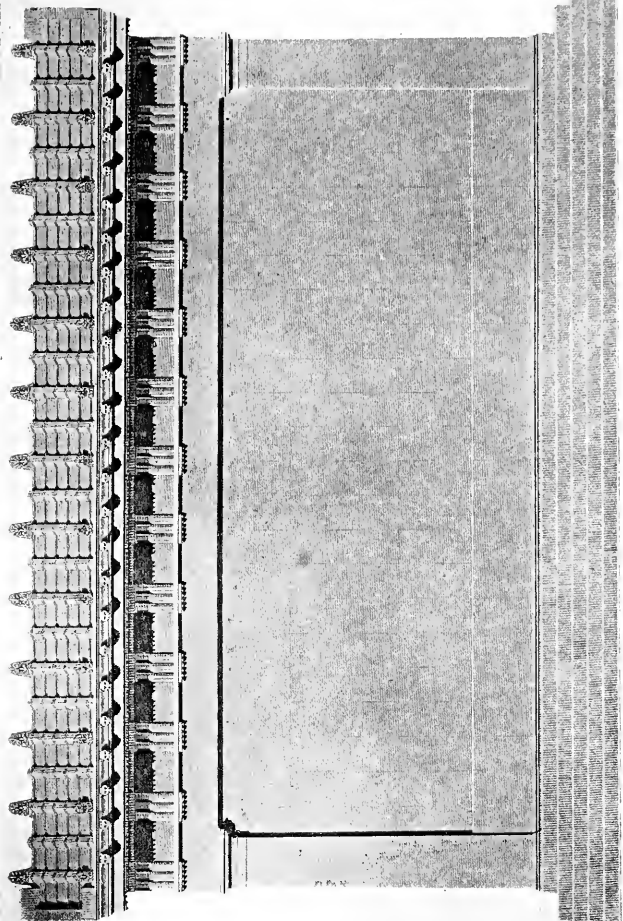


FIG. 50b.—ELEUSIS, FLANK OF TEMPLE OF DIANA PROPYLAEA.

[From the *Unedited Antiquities of Africa*.]

IV. II. Theory and Elements of Architecture

of the subtle refinements known as "optical corrections," which we shall consider fully in a later volume, are emphasised by the nature of marble. The slight rise or curvature given to the stylobate and entablature of the Parthenon



[From the *Unedited Antiquities of Attica*.

FIG. 50C.—ELEUSIS. FRONT OF TEMPLE OF DIANA PROPYLAEA.

was specially desirable in a material that came to an edge or "arris" as sharp as cast iron. Also the Pentelic surface shone with a delicacy that induced the tilting of faces in order to emphasise lines of reflected light upon important members. We shall see later that this is the essence of the design of mouldings. In the Parthenon "perpendicular faces are the exception and not the rule." (14)



[B. C. A.]



[H. B.]

FIG. 50d.—Above: ERECTHEION, FRIEZE IN ELEUSINIAN MARBLE.
Below: MODERN HOUSE, FRIEZE IN COLOUR WASH.

The horizontal lines at the foot of the building were as important as those above. We have noticed the persistence of the base, or plinth course of large stones,

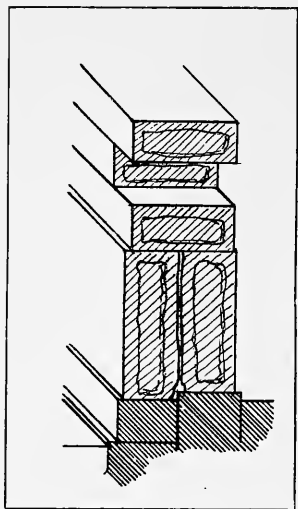


FIG. 50e.—GREEK ORTHOSTAT.
(After Durm.)

from the earliest times (Fig. 50a). This translated into marble was refined to give a series of ledges which are merely lines of emphasis or simple mouldings at the foot of the wall (Fig. 50e. See also Fig. 50b) contrasting with the vertical lines of the columns. Sometimes black Eleusinian marble was used in the base as well as in the frieze, as in the case of the Propylaea. The plinth thus refined was known as the orthostat. The wall above it was sometimes slightly tilted back.

The full life and *nerve* of the perfected monolithic building, in which the achievements of artisan, sculptor, and architect were merged, can be summoned to the eye only by the realisation also of the factors of rock, and sunlight, and brilliant colour. The progression of materials from the living rock to the red-stained antefixa of the roofs has already been examined (p. 52). What were the motives behind this achievement of sensuous joy and stern intellect

combined—this synthesis of life and art? Undoubtedly there entered into the Greek as into the Egyptian monolithic, the desire for solidity and unity. Between “Truth” and that which shall endure, a connection was recognised, and this in architecture led both peoples to the choice of the finest stones for durability and to the simplest system of equilibrium. The lintel is more *monumental* (in the full meaning of that term) than the arch because it is more enduring. But Greek values are more universal than the Egyptian; the Greeks were not concerned with the paraphernalia of an individual life prolonged beyond death¹ but with another kind of immortality. They designed and wrought deliberately “for the sake of posterity.” The word was frequently on their lips. They consciously attempted “the monumental” in the sense of an excellence that was to be a heritage to future generations; but they also achieved it. In Greek sculp-

¹ In the funeral oration of Pericles upon the soldiers who fell, early in the Peloponnesian war, there is no word of a “future life” in the accepted religious sense.

ture and Greek architecture there is distinguishable the idea of the perfect image discoverable in the existing world of men. The temple is the generalised type of the universe as the statue of the god is the generalised type of man. It was to be whole and complete both as fact and shape—compact in the face of Chaos, beautiful in the face of Mutability. The unity of the shape in combination with the strength of the structure is the supreme achievement of Greek architecture.

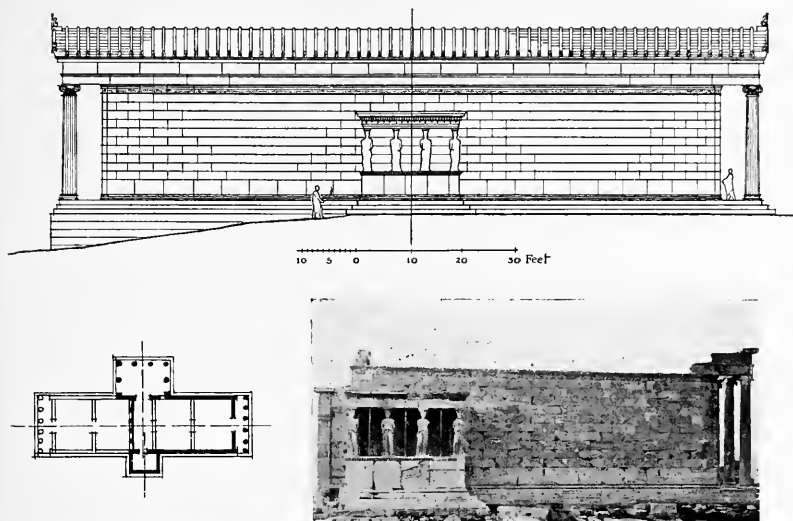


FIG. 50f.—ERECHEION AS PLANNED AND AS BUILT. GREEK USE OF THE WALL AS A BACKGROUND.

The Parthenon has survived wars and earthquakes ; its beauty still haunts the minds of succeeding generations.

The lessons, from a sternly practical point of view, to be learned from Greek building art are the lessons of observation and reasoning. The Greeks, doubtless, had great talents but they put them to work in all directions. Their buildings were vivid and interesting because, besides being accomplished structure, they included, as we have seen, the rich gifts of Greek soil and climate—the angle of light, earth-colours, plant-forms, marbles, metals, clay-products. But these gifts had to be loved and observed before they were formalised as material for art. In England to-day, we have lovely and characteristic plant-forms waiting

to contribute to our ornament, we have structural metals, able to give us wide proportions of void to solid, and fine stones that are hidden in geological museums instead of displayed in our monuments. All such factors the Greeks would have acknowledged as material for architecture. They explored fully the set of natural conditions given them. But though they drew from the widest sources, no builders reasoned so closely or discriminated so finely. The consummated temple was the result of a long train of logical but imaginative reasoning.

The Greeks revered tradition and used it always where it was still logical, as in the Parthenon.

But also, they never failed to recognise new requirements even in their religious buildings and from new requirements produced new forms, as in the case of the Erechtheion and the use of the wall intended in that building¹ (Fig. 59f).

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¹ The Erechtheion was planned as a sacred precinct to accommodate a number of ancient shrines at different levels, and to associate them in a single building. On the south flank there remains a plain wall and the enigmatical Caryatid porch. There is evidence (Elderkin's *Problems in Periclean Buildings*, 1912) that the wall was to have extended equally on either side, and this as a severe background would have given to the porch, centrally placed, a significance it now lacks. Blank wall and figurative porch would together have expressed the purpose of the precinct. "Originality" in Greek buildings can also be specially studied in their theatres, in their odeion buildings, in the Buluterion at Olympia, and in the Halls of the Mysteries at Eleusis.

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WALLS OF MESSENIA.

[Gailhabaud.

Chapter V

WALLS AND WALL SURFACES—*Continued*

1. GREEK COURSED MASONRY

THE Greeks, as we have seen, were not ignorant of "many stone" building, that is to say, of how to use stones in lines or "courses." The fortified walls of Messenia in Greece, built in the fourth century B.C. (see headpiece to this chapter), were famous in the ancient world¹ and must have had a pure masonry effect as fine as fifteenth-century Florentine. The stones are in courses of unequal height, laid dry and having the finest joints. The lowest course is the largest and forms a plinth, as in the Greek temples, but here, as our illustration shows, the plinth is finished by a slightly projecting band or string.² The vertical jointing is not continuous and some pairs of stones are trapezoidal in shape, a survival from Mycenaean and the earliest mediterranean walling.

The Messenia example shows considerable variety in the heights of courses and lengths of stones—a variety increased in effect by the occasional out-of-vertical joints occurring between the trapezium-shaped stones. This variety is specially important in the cases of modern retaining walls, dams, and abutments. Such

¹ Pausanias, Book IV., ch. xxviii and xxxi.

² Gailhabaud, J., *Monuments Anciens et Modernes*, 1850, vol. i.

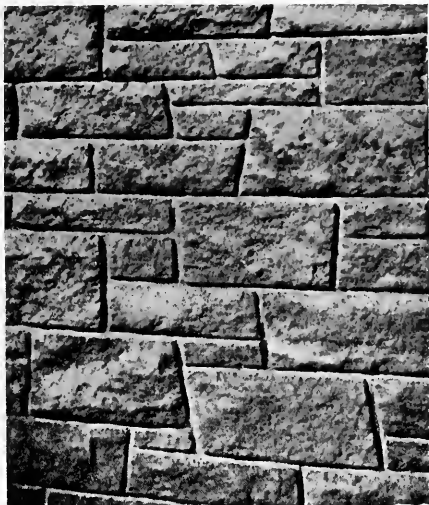
plain wall-surfaces far from being monotonous in effect, can have considerable life (Fig. 51).

Where, however, the wall surface forms one factor among others in a composition, as for instance a wall having columns related to it, the markings of the surface can afford to be uniform (Fig. 55). The Greeks have left us a beautiful example of uniform marking or "channelling" in the square base of the monument of Lysicrates at Athens (Fig. 52). Earlier examples of channelling on the walls of Greek temples and shrines exist¹ (see also the paragraphs on "rustication," v. 5), but this treatment on sacred buildings in Greece was uncommon because it was a treatment opposed to the monolithic tradition. To study marginal channelling and its implications we must turn to the works of the Roman builders.

2. CHARACTER OF ROMAN ARCHITECTURE

Turning to Rome from Athens we find a complexity of culture resembling that of the modern world. The Roman empire included Europe south of the Rhine and Danube, Asia Minor, Egypt and the African sea-board, with all climates, peoples, and building materials. Yet the shapes and organisations she produced, from Corbridge to Palmyra, bear an unmistakable stamp. Roman values, as compared to Athenian are worldly because the world and its organisation in the material sense was the Roman problem, as it is the problem of all empires. The Romans contributed to civilisation the idea of physical security over a wide area, a factor as necessary to permanent culture as the enlightenment of spirit contributed by the Greeks. The secret of that security was *order*—the first condition of great architecture.

¹ See fragment of archaic shrine in the Acropolis Museum at Athens.



[H. T.]

FIG. 51.—EDINBURGH. MODERN TRAPEZOIDAL MASONRY.

The Romans felt the attraction of Greek art and could not escape from its influence. But they were much more than mere imitators. Without joining in the discussion as to whether they originated the dome or the vault, we can be certain that they made those forms their own and expressed the Roman spirit through them. In the same way they made the Corinthian "Order" their own.

The wall in Roman building was both a great scenic expanse and also an instrument to the dome and vault. In their hands it was supremely structural and at the same time they made of it a piece of stage scenery and impresser of the public mind. This scenic quality in Roman building is connected with their orderliness and sense of symmetry. It is also a matter of pure size; the Romans were masters in the art of creating an impression by sheer mass which, as we have seen (iv. 1), is one of the first instruments of architecture. The effects they produced were monumental and deliberate

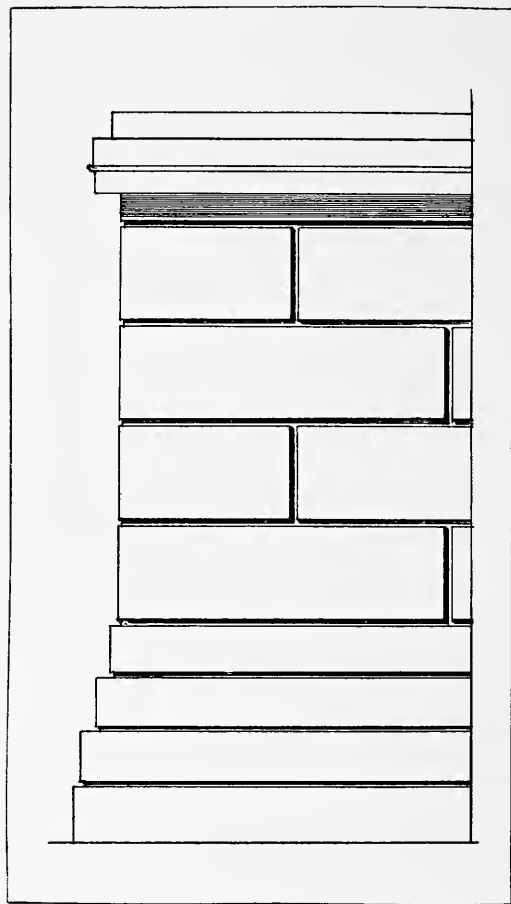


FIG. 52.—ATHENS. MONUMENT OF LYSICRATES. GREEK MARGINAL CHANNELLING.

though liable always to a certain emptiness. Their method was a method of

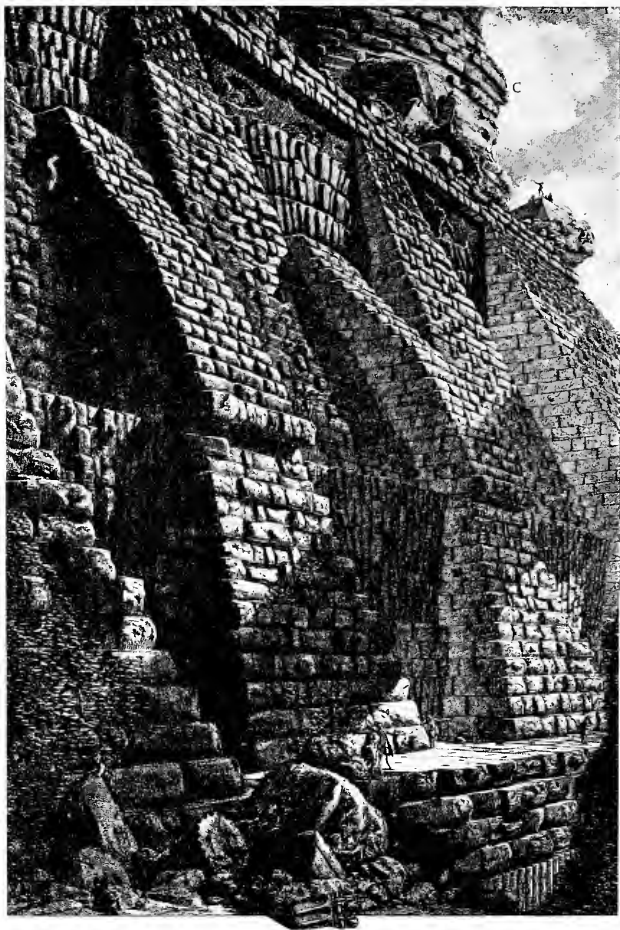
bold emphasis. This is illustrated in the solid wall placed on top of the three tiers of arches at the Colosseum (Fig. 53), and in the Roman triumphal arches where the huge attic or blocking course contributes to the massive publicity of effect as in the Arch of Titus (see tailpiece to this chapter).



FIG. 53.—ROME. THE COLOSSEUM.

Roman forms both in respect of their size and of their spectacular quality had a great influence at all times upon artists of all kinds, upon men as diverse as Michelangelo, Piranesi, and Bibiena. Piranesi's etching of the foundation wall of the Mausoleum of Hadrian (Castle of St Angelo) is a good example of this influence. Neither the structural nor the historical aspect interested the famous etcher as much as the artistic aspect. Certain obvious emotions could be conveyed by a picture that presented the spirit of Roman structure (Figs. 54 and 76). In architecture we shall see (vii. 6) that the observing and measuring of Roman ruins in the fifteenth century gave a special direction to the Italian renaissance and reasserted a Roman tradition. Michelangelo, though intensely individual in his architecture, as in his sculpture, seems to belong to a powerful scenic tradition, and this tradition—asserted strongly in the Baroque architects of the seventeenth century—can be recognised to this day in Italian building. In Bibiena it expressed itself quite logically in the scenery of the revived Classic stage. It is

an Italian talent, distinct from the Greek and from the Nordic: a genius for magnitude which has influenced the history of art at many points. It has its



[Piranesi.]

FIG. 54.—LOWER PART OF THE WALL OF THE MAUSOLEUM OF HADRIAN
(CASTLE OF ST ANGELO).

roots in the spectacular shapes made possible by Roman travertine walls and Roman pozzolana vaults.

But a rich variety of qualities, not easily analysed, must have formed the make-up of a race able not only to reduce whole nations of "barbarians" to a comfortable permanence of culture but also to convince them of its desirability. They were orderly yet adventurous, powerful, acquisitive, passionate, just, cruel. In the region of architecture they were capable of creating the dome, grandest encloser of space, and also of debasing the Greek "Orders" to a system of applied and industrialised ornament.

3. ROMAN DEVELOPMENT OF COURSED MASONRY

We have seen that the Greeks used coursed or "many-stone" masonry as distinct from monolithic or jointless, for the walls of fortresses and other secular buildings (v. 1), and that, at least in the case of Messenia, such walls had become famous in the ancient world. The deliberate emphasising of joints, and therefore of separate stones which we have noted of the Minoan (iv. 10) and the Greek builders (v. 1), was an early acknowledgment of this wall method and is discussed more fully in v. 5. Another early stone-building people, who on certain buildings allowed joints to tell and made their stones regular, were the Etruscans whose civilisation profoundly influenced the early Romans. The Etruscan stone coursing in alternate headers and stretchers (*e* in Fig. 59) became the Roman *opus quadratum* (v. 4), that is to say, a recognised system of emphasised masonry in regular lines or "courses."

But these early instances of many-stone masonry had been confined generally to secular structures while the monolithic tradition had, with a few exceptions, reigned supreme in temples and tombs.¹ The Etruscan temple is an important factor in Roman design; it was a wood and plaster building, monolithic in character, upon a masonry podium or platform² (Fig. 54a).

The Romans not only developed "many-stone" masonry for large secular structures (Fig. 57) but also applied it to temples and monumental buildings.

For long the influence upon the Romans of Greek architects trained in the monolithic was inescapable. But this influence never wholly predominated, and the history of the Roman temple is largely the history of a struggle between

¹ Except in the case of the Persian Achaemenid platforms to tombs; and the rare Greek instances of channelling (p. 127).

² See Taylor and Bradshaw's *Architectural Terra-cottas from two temples at Falerii veteres*. P.B.S.R., VIII., Pl. 1, 1916.

v. 4. Theory and Elements of Architecture

Greek and Roman ideas both in plan and structure. As early as the reign of Augustus reliefs show temples and shrines with cella walls having marginal channelling.¹ A typical Roman temple such as that known as the Maison Carrée at Nîmes in southern Gaul is the symbol of a compromise between the two systems and well expresses the compound nature of Roman culture. Piety toward Italian ancestors is maintained in the podium or base wall which is of fine masonry



FIG. 54a.—CIVITA CASTELLANA. RESTORATION OF AN ETRUSCAN TEMPLE. FLANK VIEW.
(Taylor and Bradshaw.)

and projects like the Etruscan temples. The Greek plinth course is noticeable at the foot of the cella wall and the general character of the portico and spacing of the columns are Greek rather than Etruscan. But the cella wall has crept forward to fill the space between the columns and is emphasised by strong marginal channelling (Fig. 55). Yet the grace and sweetness of the whole shape mitigates the pomp and suggests a reason why the subject races of Rome consented to an imposed culture. The Maison Carrée is fully Roman, yet is already French. Compare it, in its refined sensuous strength, to the best Louis XVI work.

4. ROMAN TECHNICAL METHODS

The multiplying and subdividing of factors in building early led the Romans to adopt regular "technical" methods which can be studied in the writings of Vitruvius. Vitruvius' *De Architectura* is a technical treatise of a high order generally admired or abused for its thoroughness. (1) It was probably written about the year 15 B.C. and shows to what a complexity Hellenistic and Roman

¹ See fragments of the frieze upon the Ara Pacis of Augustus in the Museo delle Terme.

Republican building had arrived even before the more famous buildings of the Empire had been begun. The Romans organised labour into separate corporations or building trades (2) distinguished from each other, and each the repository of a tradition and of jealously guarded empirical formulæ and recipes. Building methods were specialised; building works were carried out by agreements with contractors. Then, as now, a result of all this organising was a



FIG. 55.—NÎMES. ROMAN TEMPLE, KNOWN AS THE MAISON CARRÉE.

mechanical separation of the crafts from each other and from the body of architecture. Roman building was “machine made”—the machines being human groups. Then first arose the practice and the trade of facing walls with marble and of applying columns as decoration.

Roman walls are best classified into three general divisions. (3)

- (i) Homogeneous walls of squared stones *quadrati lapides* arranged in alternate courses of headers and stretchers. Walls of this nature are known as *opus quadratum*.

Theory and Elements of Architecture

- (ii) The walls having a facing or skin of one material and a core of another. The core consists either of rubble masonry or of mass concrete. The facings may consist of (a) small polygonal blocks of stone fitted and packed together known as *opus incertum*, or (b) small square pyramids of stone arranged with points inward and butts outward, the butts

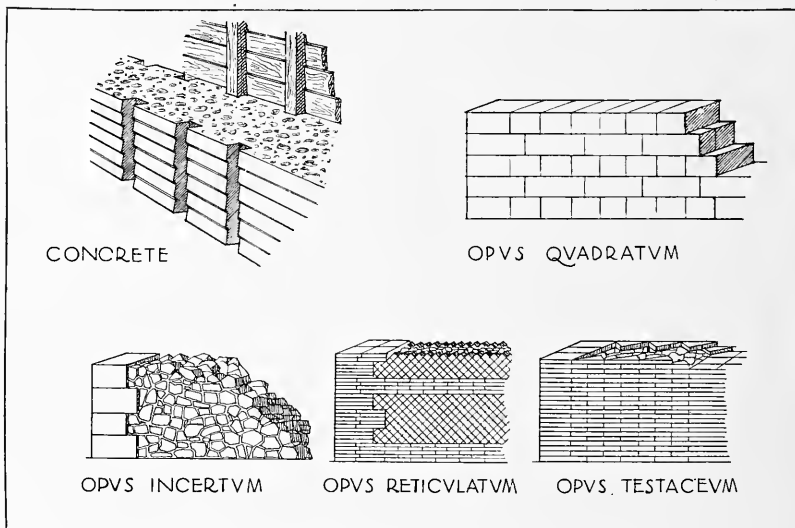


FIG. 56.—DIAGRAM OF SYSTEMS OF ROMAN WALL CONSTRUCTION.

forming a diagonal network known as *opus reticulatum*, or (c) triangular bricks known as *opus testaceum*.

- (iii.) Concrete walls.

These various types are illustrated in Fig. 56.

(i.) The *opus quadratum* is Etruscan in origin. It is a whole system of wall construction, and should be distinguished from *opus incertum* and *reticulatum*, which are only different methods of facing in the same system. The *quadratum* was a true masonry, and is characteristic of republican building; it had headers and stretchers of standard size in alternate courses, and each stone was fastened to

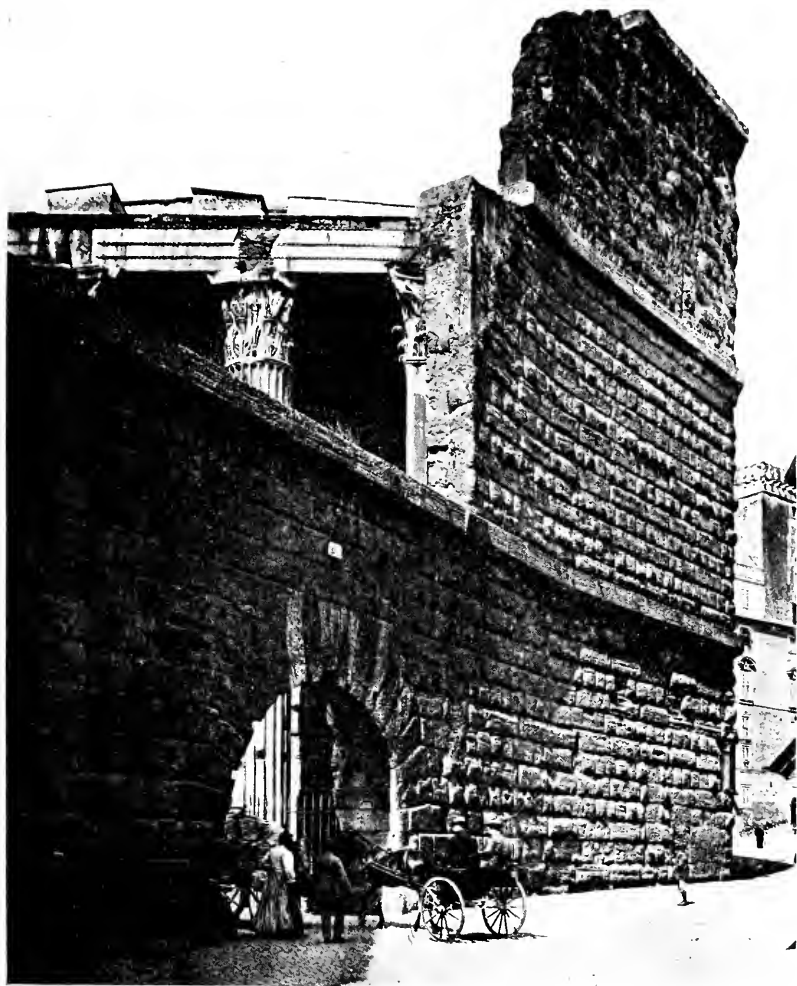


FIG. 57.—ROME. EXTERNAL WALL OF FORUM OF AUGUSTUS, OF TUFFA BLOCKS IN *opus quadratum*.
Voussoirs and Strings are in Travertine.

its neighbour by large iron cramps or dowells run in with lead. In the front of the Tabularium (78 B.C.) and in the outer wall of the Forum of Augustus (Fig. 57)—both good examples of *quadratum*—the headers are a square of two Roman feet and stretchers four feet long.¹ The system of alternate headers and stretchers was termed “enweaving” or “emplecton.”

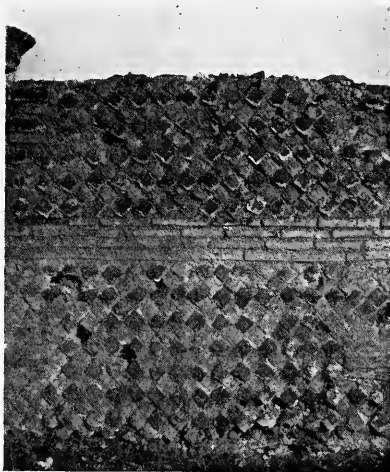


FIG. 58.—OSTIA. *Opus reticulatum*, COMPOSED OF ALTERNATE PYRAMIDS OF TUFFA AND SELCE, BETWEEN BRICK-BONDING COURSES.

Mortar was known from very early times in Rome. Its purpose originally was not to serve as a cement but was rather to give an even distribution of weight over the whole bed. For this purpose it consisted (as in some of the beds in the Egyptian pyramids) merely of a very thin skin of lime between the smoothly fitting surfaces of the stones. In masonry the mortar joints remained fine, in brickwork they soon became wider (v. 10). The *opus quadratum* was given up in the third century.

(ii.) In the *opus incertum* (Fig. 56) the polygonal blocks were usually of tufa about five inches across. This system of walling was extensively used at Tibur (Tivoli) and at Praeneste; but it is only a transitional method,

and before the time of Augustus had already developed into the *opus reticulatum* (Fig. 56) in which the butts of the tufa blocks are squared, made regular in size, and laid to run in diagonal lines, thus giving the appearance of a *network* which gave rise to the term. This method was quickly improved upon; special tufa quoins, polygonal in shape, were made for angles of walls, and the reticulated lines of facings were rendered exact. At Ostia alternate tufa and selce blocks, are found (Fig. 58). Vitruvius states, that *opus reticulatum* was not as strong as the older *opus incertum*. (1) After Trajan's time the angles of walls were built in brick and the wall itself was strengthened

¹ The Roman foot is approximately equal to 11.7 inches, or about $\frac{1}{4}$ inch less than the English foot. The Greek foot was a fraction less, 0.97 of an English foot. (Middleton, *Remains of Ancient Rome*, 1892, p. 38.)

by brick-bonding courses at regular intervals. The reticulated parts then became panels. The method was expensive, and its elegant surface was generally concealed by a coat of plaster (v. 10).

The most common method of facing a composite wall was by means of brick (Fig. 56), sometimes called *opus testaceum*.¹ Triangular bricks were generally used with apex tailing into the concrete core. This core was not different to the concrete walls discussed in the next paragraph, and these three methods of facing—the *incertum*, *reticulatum* and *testaceum*—may be considered as varieties of an essential concrete construction. The concrete core did not form a single piece from top to bottom of the wall but was divided into sections by bonding courses of bricks going right through the wall from face to face (Fig. 58). The wall thus became a series of superimposed cells filled with concrete. A brick wall as we understand it to-day built in baked bricks throughout, did not exist in ancient Rome; even partition walls, 7 inch thick, consisted of an inner core of concrete faced with small triangular bricks. Roman brickwork is more fully treated in v. 10.

(iii.) *Roman Concrete*.—A great and distinctive contribution of the Romans to structure was their development and application of concrete. Yet they only made use of the materials ready to hand (iii. 3). There existed all over the site and the neighbourhood of Rome thick stratas of a volcanic earth called *pozzolana* which lay where it had fallen from the craters of the Alban hills (iii. 3). Pozzolana was used by the Romans for every structural purpose,² and we find a whole chapter of Vitruvius devoted to it. (1) The lime generally mixed with the pozzolana was got by burning *Travertine*, a river-bed limestone equally abundant in the neighbourhood.

Concrete was used for foundations, for walls and for vaults, and from the first century B.C. onwards was the commonest building material used in Rome. The concrete walls were cast between timber shuttering having the "struts" on the inside (Fig. 56); the marks of the boards and struts are still to be seen on foundations and sub-structures. Greater care was taken with the aggregate of the wall than is usual to-day. The mass consisted of the pozzolana cement and a smaller-sized aggregate consisting of broken lumps of tufa, peperino, and later brick-bats. This aggregate was poured into the shuttering to a certain height, then a layer of larger stones was placed by hand and spaced like plums in a plum pudding, then came another layer of smaller aggregate. Shuttering was used

¹ From the word *testae*, meaning kiln-burnt bricks as distinct from the *laterites*, or sun-dried bricks.

² It was even worked into the clay and used for the best bricks.

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to retain the brick facing in the case of Nero's Golden House and the *Thermae* of Titus,¹ and in some cases timber ties were left through the concrete core to tie in the shuttering and later withdrawn. Concrete walls of great thickness were made in this way. Yet the Romans were uneconomical of effort in one important respect. These walls could well have been plastered directly upon the concrete. Instead the concrete was generally faced in one of the methods described, and then plaster applied to the facing. But the modern method of raking out brick joints in order to give a key was apparently unknown and a key for the plaster was laboriously formed by inserting nails or marble plugs into the facing.

5. *RUSTICATION*

The Roman method of bold emphasis in design is illustrated in their use of what is called rustication. Rustication is an emphasis on mass, and consists in increasing the appearance of strength in a continuous wall by placing a margin round beds and joints and thus defining each stone as a unit. When the surface of the stone is left rough or "rock-faced" the appearance of strength can be still further increased.² This method of treating masonry is the opposite of the monolithic method. It is controversial whether early rock-facing was done deliberately for effect or was merely the result of not reducing the masonry to a finished surface. (4) But whether deliberate or not the architectural effect is obvious. Some Greek examples of rustication have already been touched upon at the beginning of the chapter. In Fig. 59 the subject is expanded; the illustrations are not placed chronologically. In (a) is shown one of the *faïence* tablets discovered by Sir Arthur Evans at Knossos in Crete illustrating an early Middle Minoan town house. The method of building was to lay limestone blocks on thick beds of clay mortar. (5) The courses on the tablet are regular in height and the vertical joints come over each other. The *faïence* tablets show also walls having horizontal timber beams at regular intervals (Fig. 145), and the lines of the construction, whether stone or timber, are emphasised and used artistically. The apparent "rustication" in the example here given may not have been due to the desire of increasing the appearance of strength but the

¹ Middleton, J. H., *Remains of Ancient Rome*, 1892, p. 49.

² The term *RUSTICATION* is sometimes used for rock-facing only; but generally includes the plain "channelling" or grooving of joints. The definition given by the *A.P.S. Dictionary* is as follows:—"*RUSTIC WORK; RUSTICATION.* (Fr. *gresserie* ou *graisserie*; *bossage*; *champtre*, BLONDEL, *Cours*, 8vo, i., 417.) The terms in general use for that species of masonry in which the several stones in each course are distinctly marked by a square sunk joint or *GROOVE* (ANGLET), or chamfered or otherwise cut."

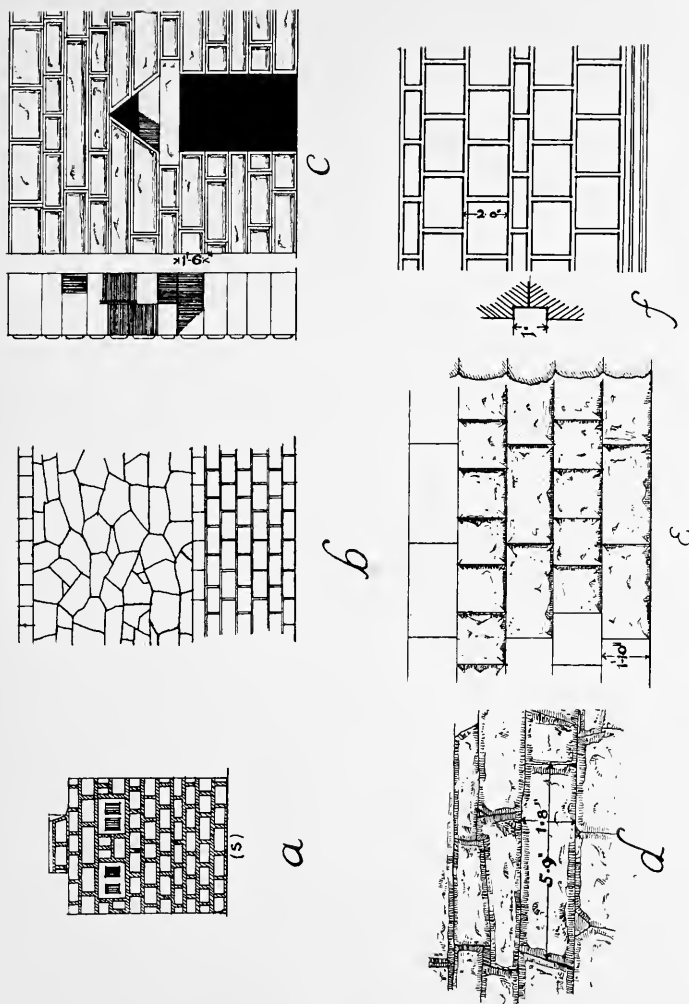


FIG. 59.—RUSTICATION AND ROCK-FACING.

(a) Knossos, faience tablet [Evans]. (b) Cnidus, Greek wall in regular and polygonal masonry. (c) Iassus, theatre wall [Gailhabaud]. (d) Fiesole, rock-faced Etruscan wall [Dum]. (e) Falerii, Etruscan masonry. (f) Rome, cella wall of Temple of Vesta on the Tiber.

result is certainly to emphasise each particular stone and is, so far, the opposite of monolithic.¹

A Greek wall at Cnidus, probably of the third century B.C., was built "with large polygonal blocks fitting accurately together with drafted edges round each block. . . . The selection of polygonal masonry would seem to have been due to the fact that the Greeks recognised its decorative value." (6) This wall is illustrated in (b). The polygonal masonry is built upon a base of regular coursed masonry.

The beautiful Greek coursed masonry of the fourth century B.C. in the walls of Messenia has already been referred to (p. 126); but at Messenia the margins of the joints were not drafted and the rock-facing was due to leaving the surfaces of the stones, in a common-sense manner, as they came from the quarry. But in the Hellenistic theatre at Iassus in Asia Minor, rock-facing with drafted margins is found. This is illustrated in (c). The result is a true rustication, as strong and varied, and as remote from the monolithic, as the Florentine example (j). The Greek wall, like the Florentine, had courses of unequal height and the stones break joint unevenly. The Greek, however, consists of marble blocks laid dry, the Florentine has mortar. The theatre at Aspendus also shows a fine rusticated supporting wall.

The Romans had ancient Italian as well as Greek models to follow in the matter of fine wall surfaces (v. 3). In (d) Fiesole and (e) Falerii are shown two different Etruscan examples. The Etruscan dry-masonry wall consisting of alternate courses of headers and stretchers as found at Bieda and at Falerii (7), was adopted by the Romans and became their *opus quadratum* already referred to (v. 3). Good Roman examples are the external wall of the Forum of Augustus (Fig. 57) and the Tabularium at Rome. The surfaces in Roman *opus quadratum* are left rough, there is no drafted margin to the joints and some stones project more than others. The joints are exceedingly fine and mortar, if it occurs, is not for adhesive purposes but for the distribution of weight (p. 136). The effect is more monotonous than the Greek or the Florentine but is very impressive. The ancient Etruscan walling at Fiesole (d) is an interesting example of early rock-facing with a drafted margin. (8) The treatment is applied to stones polygonal in shape.

The Romans appear to have left the masonry of their amphitheatres rough in several cases, probably for economy's sake. This occurs at Verona (Fig. 59a), Viterbo, and Pola (g) and on the Porta Maggiore, Rome (Fig. 76). The result in

¹ Sir Arthur Evans refers to "the appearance in the case of the terra-cotta (model) shrine of distinct interstices between the blocks." (5)

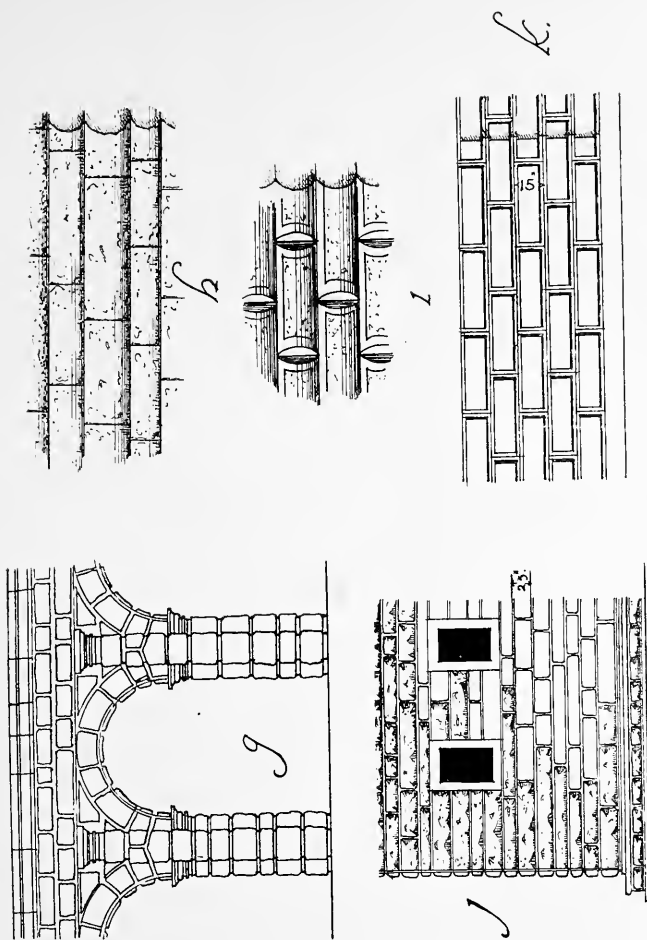


FIG. 59 (continued).—(g) Pola, rock-faced piers to amphitheatre. (h) Alinda in Asia Minor, wall of stoa. (i) Ephesus, Roman convex courses [Durm]. (j) Florence, Strozzi wall. (k) Late Renaissance rustication from Chambers.

all these cases, whether intentional or not, is the appearance of rustication,¹ though not always the appearance of strength (v. 8).

The Classic builders developed a kind of intermediate rustication, the effect of which was to emphasise each *course* as a unit, by laying courses cut to a continuous torus or cushion shape. A Hellenistic example of this occurs on the base of the stoa at Alinda in Asia Minor (*b*). The courses are worked to a convex curve but vary in height and in projection. A great impression of weight is conveyed by this means. The Romans built some magnificent masonry of this kind at Pednelissus in Asia Minor; at Ephesus they carried convex rustication further and emphasised each stone by a wide splay at the vertical joints as in (*i*).



FIG. 59*a*.—VERONA. PIER OF AMPHITHEATRE
IN ROCK-FACED VERONA MARBLE.

The fine Greek channelling on the base of the monument of Lysicrates at Athens, already referred to (Fig. 52), was a true emphasising of the joints of stones. But the Romans frequently applied thin marble slabs to a brick or concrete wall and channelled the slabs. A typical example is the circular temple of Vesta² on the

Tiber at Rome (*f*). Here variety is had by introducing a narrower course at regular intervals. The Romans, for the sake of effect, carried this channelling of facing slabs to extremes of artificiality. In the tomb of Caecilia Metella the sunk margins do not occur at the joints of slabs, but the slabs, oblong in shape, are drafted so as to represent a number of stones. In the temple of Vesta in the Forum Romanum the facing slabs are also channelled without regard to the position of the joints. This is the least satisfactory kind of rustication. It is also found upon the travertine slabs of the Palazzo della Cancelleria in Rome.

The Florentine rustication of the fifteenth century illustrated in (*j*) (Strozzi

¹ Examples in Rome of rock-facing with drafted joints are also to be found on the Servian Wall.

² See Garnier's drawing in d'Espouy's *Fragments Antiques*, vol. i., pl. 40.

Palace) is the finest of wall surfaces from every point of view. Like the Greek example (c) (Iassus) the courses are unequal in height and the stones break joint irregularly. Here and there stones project farther than others.

In later Renaissance times rustication tended to become uniform and mechanical as in (k), and to resemble again the Roman channelling of marble slabs. But if a modern wall is really massive, rustication is still logical. The size of the courses and stones must bear a relation to the expanse of wall. This is important. Too large a course will dwarf the wall and destroy the effect of mass. Examples of this are seen everywhere in our streets. A good average size for a rusticated

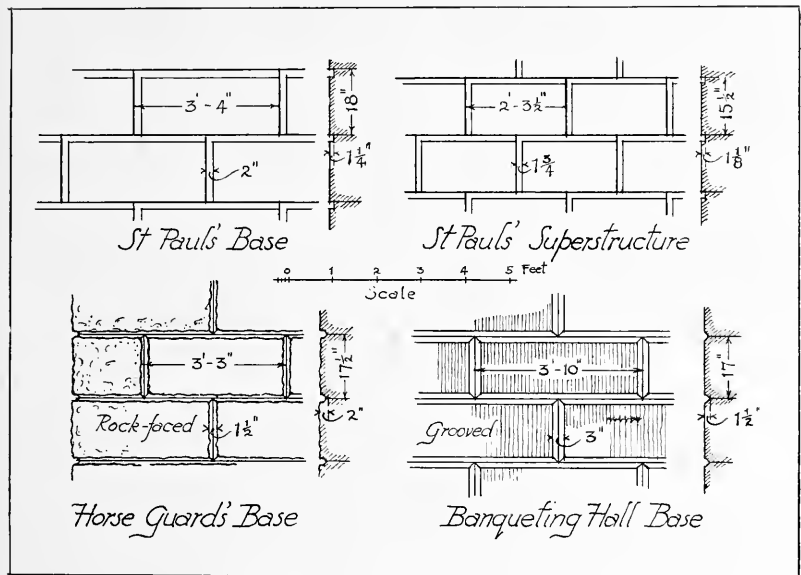


FIG. 59b.—EXAMPLES TO SCALE OF UNIFORM RUSTICATION.

course is 15 ins. or 16 ins. Some good examples with their sizes are shown in Fig. 59b. Joints need not occur in the centre of the marginal channels, but along their edge as in the case of St Paul's ¹ (Fig. 59b).

¹ The following are some further sizes of rusticated courses: Somerset House, London, 16 ins.; Covent Garden Opera House, 22 1/2 ins.; Bow Street Police Station, 12 ins.; *Morning Post* Building,

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But when all is said in favour of this uniform kind of rustication, there is no doubt that the ancient common-sense method of courses unequal in height and with stones just breaking joint, produces the finer and more interesting surface.

6. RENAISSANCE MASONRY

Throughout the Middle Ages ordinary Italian masonry was generally laid in courses of unequal height with the faces left rough. The rock facing appears to become deliberate towards the fifteenth century. Arch stones or "*voussoirs*," long and rock-faced, are noticeable in Italian pointed arches and merge imperceptibly into the *voussoirs* of the Renaissance type. The Palazzo dei Signori in Florence has a fine masonry contrast between the rock-facing of the main structure and the smooth ashlar above the corbelling. The Palazzo Castellani at Florence shows also a medieval masonry treatment (Fig. 59c). The Italian Renaissance builders of the fifteenth century had before them these medieval walls and also the fine regular examples in the Roman Forum of Augustus (Fig. 57).

In the front of the Pitti Palace, begun by Brunelleschi in 1435, we find a re-assertion of Roman values (Fig. 60). But there is a difference. The expression of power is there, but it is now the power and dignity of an individual or of a family not of a State or an Empire. Italy of the *quattro-cento*¹ is a group of rival states resembling Greece of the fifth century B.C. but unified by a dominant church. The grandest manners in architecture are now at the service of the wealthy individual whether duke, merchant, or ecclesiastic. But the individual was at no period in history more inquisitive and active in spirit, nor more dependent for his enjoyment upon the artist. Intelligence of shape was to the Italian mind a language and a necessity. Against the complexity of medieval theology is now set the profound simplicity of a work of art. Angels, campaniles, walls, loggias, were joyful shapes which were understood and appreciated by all citizens. Thus the development of the artist was bound up with that of the patron of art. Alberti, an Italian architect and writer, describes both the ideal painter and the ideal architect. The ideal architect "ought to be a man of fine genius, of a great application, of the best education, of thorough experience and especially of sound sense and firm judgment that presumes to declare

18 ins.; King's Inns, Dublin, 15 ins.; Boston Public Library, 17 ins.; Broadway Savings Institution, N.Y., 15 ins.; University Club, N.Y., 25 ins.; Montreal, Bank of Montreal, 23 ins.

¹ The "fourteen hundreds," *i.e.* the fifteenth century.

himself an architect.”¹ Whether for better or for worse the individual architect emerges as a scholar and gentleman distinct from the artizan. “The Renaissance artist was indeed to fulfil the idea of a perfectible human nature, the conception of which is the best gift of Humanism to the modern world.” (4)

It is not surprising that the home or palace of the wealthy patron should

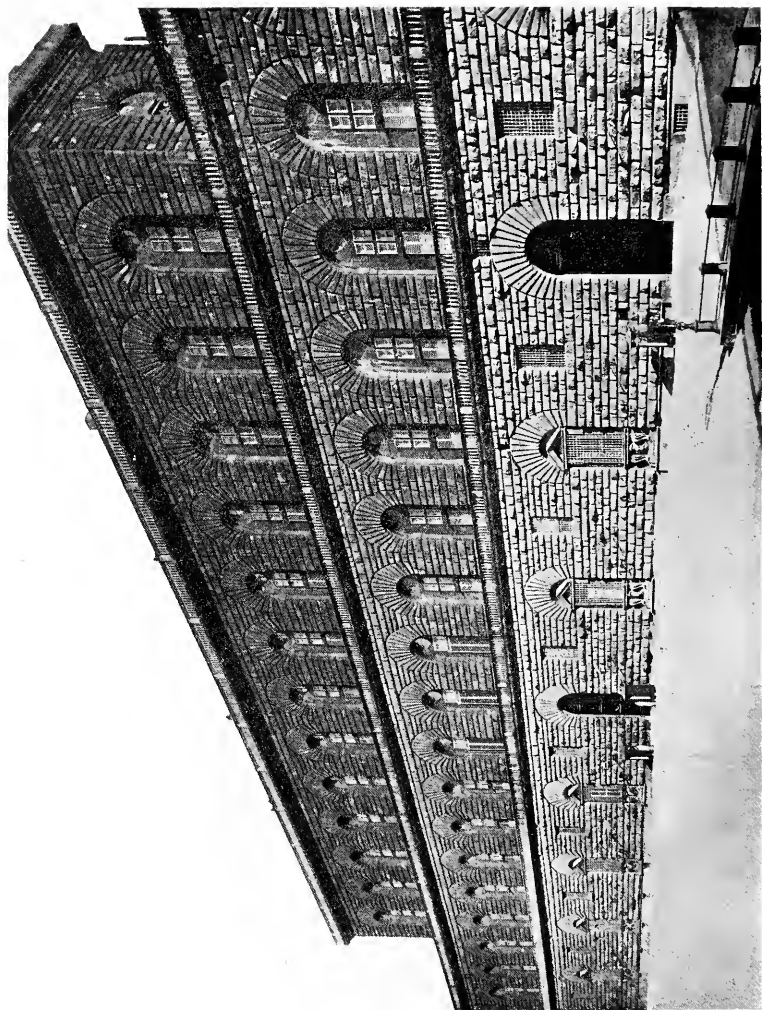


FIG. 59C.—FLORENCE. PALAZZO CASTELLANI.

[Alinari.]

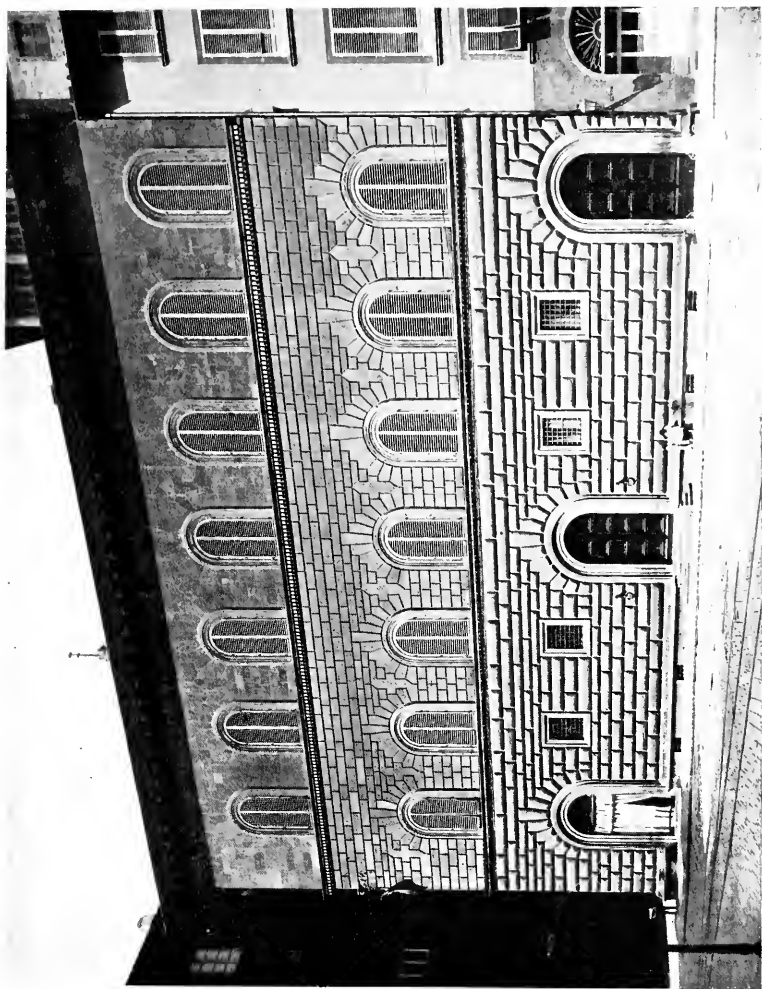
become the typical building of the Italian Renaissance. Both Italian and French writers on architecture elaborated the ideal palace as a theme, and it was a theme not confined to technical treatises. In Bacon's essays there is an elaborate de-

¹ Alberti, L. B., *De Re Aedificatoria*, 1485. Leoni's translation into English, 1726, Book IX., ch. 10.



[Alinari]

FIG. 60.—FLORENCE. PITTÌ PALACE, MAIN FAÇADE. (*Brinnetleschi*.)



[Alinari.]

FIG. 61.—FLORENCE. GONDI PALACE. (Giuliano da San Gallo.)

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scription of the perfect palace. All the great architects were at work upon such palaces.¹ Kings, dukes, wealthy ecclesiastics, and merchant princes rivalled each other in expenditure and in connoisseurship. Beauty was desired and was had, and wealth was spent in the search for it. Architecture requires wealth as well as the desire for culture. The result was a body of artistic achievement which remains one of the chief inheritances of the European peoples. The house of the Florentine gentleman, with its works of art, could be converted into a picture gallery and museum for later generations with scarcely a change in its arrangements, and the Florentine palace became almost inevitably the early type of the public picture gallery—a type that persisted well into the nineteenth century. An example of this is the National Portrait Gallery in London.

The wall surface in Italian Renaissance architecture received considerable attention. It was often of an exaggerated impressiveness. In the Pitti Palace (Fig. 60) the exterior elevation, as distinct from the courtyard, consists of broad expanses of rock-faced masonry in unequal courses, some of the stones projecting as much as two feet from the plane of the wall. The result is a combination of texture and solidity unsurpassed.² In the Gondi Palace (Fig. 61) the building is entirely made by three different ranges of masonry walling one upon another. The lowest range consists of large cushion-shaped stones divided at intervals by arches having emphasised voussoirs; the range above consists of a smoother wall having unequal courses with the joints channelled; the top range consists of smooth ashlar. The simple effects thus obtained have not been surpassed by the most complicated architectural treatments.

The range of character that can be given to buildings by varying the rustication can be well seen when the Gondi (Fig. 61) with its smooth grace is compared to the Pitti (Fig. 60). Also compare and contrast the Forum of Augustus (Fig. 57), the Federal Reserve Bank in New York (Fig. 63), and Scotland Yard (Fig. 64).

But the excellence of all good examples of rustication—without any exception—is due to the existence of and emphasis upon *mass*. We have seen that Florentine geology contributed to the character of Florentine masonry (iii. 3) by reason of the sizes of stones available. If a wall is truly massive—then the mass can be emphasised successfully by rustication and by means of deep

¹ See *Appendix, Note 4*.

² These effects were deliberately sought after. Vasari in his chapter on rusticated masonry, after mentioning the Pitti and Strozzi by name, says: "When well designed, the more solid and simple the building, the more skill and beauty do we perceive in it, and this kind of work is necessarily more lasting and durable than all others." (4)

“reveals” (viii. 3). If the wall is *not* truly massive but is a screen wall in front of a steel frame—serving quite a different purpose—then rustication will be, and will tend to look, bad art and the shallow reveals will give a pasteboard appearance to the front of the building.

7. MEDIEVAL MASONRY

The early monastic builders had the ruins of the Roman empire to imitate and the remains of a Roman building tradition to guide them, but they lived in isolated undeveloped communities where stone was expensive, and they were without machinery for conveying and lifting heavy weights. Under these restrictions it was natural that they should follow the Roman system of wall facing and core (v. 4), using small blocks easily handled for the external shell. They were without the Roman special knowledge of cement concrete and their rubble cores were weak. (9) The blocks were rough axed and set with thick joints in an inferior mortar. With the perishing of the cement the rubble core became a dead earthen weight imperfectly retained by the small stones. Long wooden beams were placed in the length of the walls in order to stiffen them; these soon decayed and left hollows. Buildings frequently collapsed and new experiments were made. From the most amateurish beginnings they developed masonry technique through various phases until finally the magnificent stone carpentry of the fourteenth and fifteenth centuries was reached. But the rubble tradition was always liable to *vitiare* the achievements of the great cathedral builders. In England the tradition of the heavy central tower over the crossing demanded, for safety's sake, the finest technical construction of the supporting piers. Yet in numberless cases the masonry of these piers has been found to provide quite inadequate bearings, owing to the falling away in each pier of a large rubble core leaving the weight to be carried upon the shell. This rubble core tradition caused the fall of many medieval churches and even reached and damaged Wren's cathedral church of St Paul as late as the seventeenth century. In this respect the great medieval buildings do not compare well with the achievements in durability of the Egyptian, Greek, and Roman builders.

The Gothic cathedral wall however, is the finest example of wall as instrument to the vault. In medieval times many Roman vaults survived (Fig. 28*a*), and were a continual stimulus to inventive builders. We have seen also that the Romans left the stone quarries of Gaul as a heritage to Europe (p. 72). The medieval vault had to rest not upon a massive wall of pozzolan concrete but upon a much

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thinner wall of limestone rubble. But the exploring of the quarries led, as we have seen, to the selecting of stones of large dimensions for special functions in the wall (p. 76), and thus to the progressive concentrating of loads upon points. (That is to say reliance was placed not upon sheer mass and the tensile strength of the cement but rather upon a scientific membering of the skeleton of the wall to take the necessary stresses.) In France this membering achieved a marvellous skill and elaboration and the demands of the vault wholly determined the development of the wall.

The French Gothic vault, spanning perhaps 60 feet, and reaching a height of as much as 120 feet above the church floor, exerted (i.) a vertical pressure or "dead load" downwards, and (ii.) a horizontal pressure or "thrust" outwards. The load at such a height had to be carried by a light, strong, clerestory structure able to transmit stress downwards without too much increasing the total weight, and we have seen that the French clerestory resembles in many cases a hollow boxing in stone (Fig. 32*a*). But for the sake of stability the "thrust" required to be opposed by mass; hence the large lateral buttresses of French Gothic (Fig. 31). The mass instead of being evenly distributed like the Roman between walls, buttresses, and vaults, is concentrated in the buttresses and used mainly to resist vault thrust. Pinnacles were added to buttresses to increase stability (iv. 3). In the section of Reims (Fig. 62), if we compare roughly the mass of the nave wall alone to the total mass of the buttresses the former can be seen to be the lighter. In course of time the wall became frankly a framework for areas of stained glass. On any cathedral plan (Fig. 110) this can be realised; the wall area appears to be divided into sections and the sections turned at right angles to the lines of thrust of the vault.

In England the vault principle was less highly developed, and the wall in consequence is less of a skeleton; the churches are not as lofty, and appear more solid. Compare and contrast the contemporary churches of Salisbury and Amiens.

But if we compare the Gothic vault of Reims (Fig. 62) to the Roman, in the Baths of Diocletian at Rome (Fig. 28*a*), it can be seen that the principle of the Gothic structure is inherent in the Roman. The Roman groins likewise deliver thrust to a series of points which require buttressing as well as adequate bearing. But there is in the Gothic a recognition of the design value of concentrated loads and of transferred thrusts. The constructive process is displayed and enjoyed for its own sake. Mass, so far from being emphasised like the Italian, is minimised. The buttresses are only just massive enough for their purpose;

walls are pierced wherever possible ; ornament is had by a kind of cutting out and leaving of voids where solids might be expected. But this is the opposite of the design values we have been discussing in the preceding sections of this chapter. The Greeks used "mass" as the very instrument of permanence,

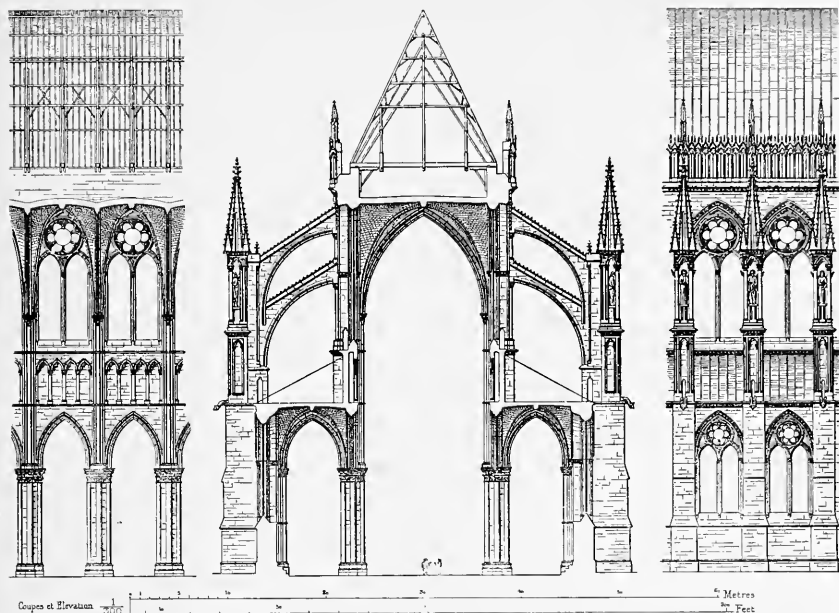


FIG. 62.—REIMS. SECTIONS OF NAVE. (From T. H. King.)

refining and transforming it, but relying upon it. The Romans and Italians emphasised it for the sake of its spectacular value. But here is an aim quite different. Not mass the property of matter, but lightness and the defiance of mass is here attempted with success. Mass does not here enter into the monumental idea at all. The characteristic Gothic element is indeed not wall but roof ; an analysis of medieval values is given in the chapters on roofs (vii. 5).

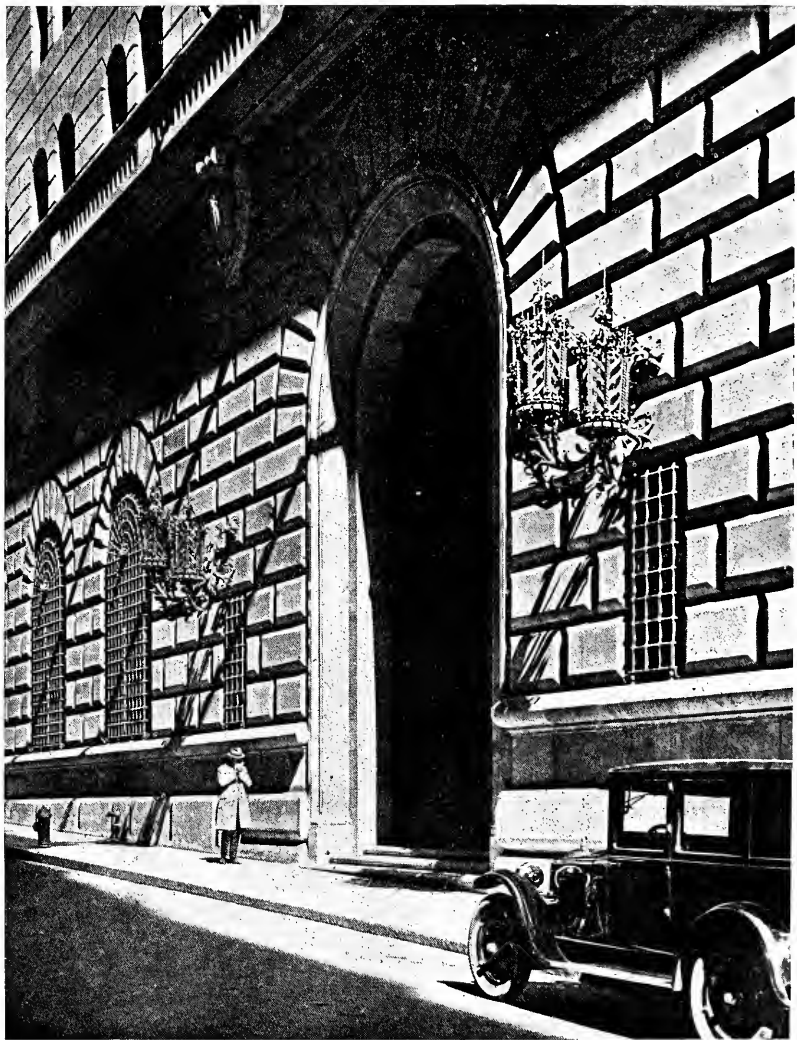


FIG. 63.—NEW YORK. FEDERAL RESERVE BANK. RUSTICATION AND REFLECTED LIGHT.
(York and Sawyer.)

8. MODERN MASONRY

In some modern city buildings such as large banks, public baths, or government offices, massive masonry walls are as reasonable to-day as in the past. In such cases a fine masonry quality properly emphasised will produce fine effects. In our illustration (Fig. 63) of the Federal Reserve Bank in New York the grand tradition has been followed with sense and delicacy; and shows that the best modern American rustication is as expressive as ancient Italian. But rustication always requires a bright light, and a reflected light, in order that its true values shall tell, and is therefore more successful in America than in the British Isles. The reflected light striking upwards is clearly shown in our illustration of the Federal Reserve Bank.

For the emphasising of sheer mass where it occurs in modern masonry there are other means besides rustication of the Italian kind. Large evenly-distributed loads on the lower parts of buildings can be well emphasised by tooled surfaces of granite without rustication, as in the Scotland Yard building in London (Fig. 64). Here the courses and sizes of stones are uneven. Each stone is emphasised by giving a different direction to the tool while working round the margins. Tool markings could be left with advantage on many kinds of masonry—kinds that are now rubbed smooth.

But in many city buildings steel or concrete stanchions and beams form the bones of the structure and carry the weight, and masonry is used chiefly as a protector against the weather. Stones can therefore be cut thinner than if they had to carry weight, and the *panel* rather than the *course* becomes the reasonable masonry form. We have seen that rustication is an emphasis on mass and that the least satisfactory kind of rustication was the Roman method of channelling facing slabs (*f* in Fig. 59). Slabs or panels require a quite different kind of emphasis. An example of masonry treated frankly as a panel, clothing a steel frame beneath and protecting it from the weather, is illustrated in Messrs Heal's shop, Fig. 65. The bronze bolt heads on the smooth marble expanse and the other metal fittings seem to express the double material. This protecting from weather—the function of the screen—is a difficult problem in a smoke-laden atmosphere, and directly influences design. A stone surface in order to be seen must reflect light (ii. 3); if it goes wholly black it disappears from sight, as many fine buildings still standing have disappeared. Also it must resist the acids in the atmosphere or it will decay rapidly. Many of the grit stones will resist decay but turn quite black as in the case of the Leeds Town Hall. Granite is a stone which is not

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only excellent for carrying loads but also resists atmospheric acids and remains



FIG. 64.—LONDON. SCOTLAND YARD. TOOLED GRANITE IN UNEVEN COURSES. (*Norman Shaw.*)

visible. It has been used therefore, with good effect not only massively as in Scotland Yard but also in thin slabs, as in the Kodak Building illustrated in Fig. 66.

Limestone from the Portland beds has won first place as a London wall surface owing to its resistance to acids and to the fact that under the combined influence of smoke and rain it turns from a cream colour into black and white. The white parts reflect the light: they occur in London on the south and west aspects, that is towards the prevailing wind, and this fact should be considered in design. Limestones can be treated as panels reasonably enough since they are generally applied as a mere skin 9 inches thick to a brick backing. For further panel treatments see the next section (v. 9).

Since rustication is the emphasising of distributed rather than concentrated loads it should not be used upon narrow points of support such as piers and columns. We have seen that, for a good reason, the Greek builders insisted on the monolithic character of a column even when that column was built up of drums (p. 118). In modern buildings in large cities the lower parts are generally narrow piers where the load is obviously



FIG. 65.—LONDON, MESSRS HEAL'S SHOP. MASONRY TREATED AS A PANEL. (*Smith and Brewer.*)

v. 9. Theory and Elements of Architecture

concentrated; the customary rustication of these piers gives the appearance of weakness not strength. The main front of the Pitti Palace in Florence, by Brunelleschi (Fig. 60), has been referred to as a fine example of the use of rustication. But the same palace in its courtyard, by Ammanati and others, presents the converse (Fig. 67). Here the horizontal lines of the channelling are carried over columns and imposts of arches with an effect of weakness—the opposite of what was intended. The same may be said of the Roman amphitheatre at Pola, as illustrated in *g* in Fig. 59. But the evils of rustication without mass are specially seen in the modern practice of horizontally channelling screen walls, angles, and shop corners. Rustication here is a wrong emphasis. Instead the modern city building, for the reasons we have shown, calls for the true monolith pier below and the panel above. (See also *x. 6.*)



FIG. 66.—LONDON. KODAK BUILDING. GRANITE USED IN THIN SLABS. (*Burnett and Partners.*)

9. THE PANEL

The logical use of the panel as a filling of one material between a framing of another is not a modern development. The Persian builders of the Achaemenid period built panels of mud-brick between stone piers (*iv. 9*). The problems connected with the non-homogeneous wall in

Tudor times produced some interesting building forms. In English half-timber work, oak or elm was used for the frame of the house, and the intermediate panels were filled with battens or “brick nogging” and plastered over. At first the wooden posts of the framing were placed very near together and the intermediate panels were very small. This method was called “post and pan.” (*10*)

Later the horizontal or transom members became as important as the post, and the panel increased in size (*see* Fig. 68). Fine contrasts of material were obtained in this way when the wood frame was left exposed. The plaster of the panel, however, was frequently carried over the timber also, in order to protect it from the weather. Then the position of the timbers beneath gave rise to the plaster margin between the panels, and the panels frequently came



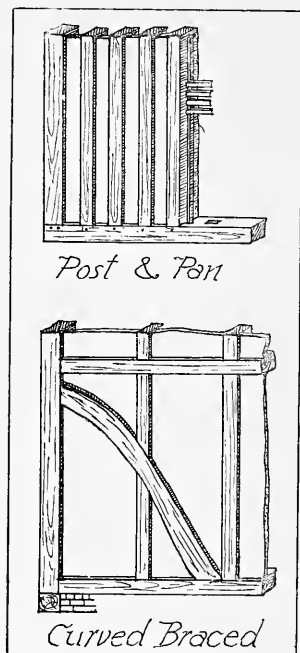
FIG. 67.—FLORENCE. PITTÌ PALACE, GARDEN FRONT. (*Architect, Ammannati.*)

to be covered with patterns in plasterwork. A fine example of a Hertfordshire wall treatment in plaster is shown in Fig. 69.

English Perpendicular architecture, was also an architecture of the panel. Masonry was used for the frame and glass for the filling. Henry VII.'s Chapel at Westminster, King's College Chapel at Cambridge, St George's Chapel at Windsor are good examples of this kind of wall treatment. The building tended to become a single large hall having glass panels. In the Perpendicular church transepts and triforium were swept away owing to the same movement. The modern steel and glass exhibition building is structurally of the same type. Where glass is used in direct contact with masonry it is necessary to fit it in frames having a certain elasticity. The lead framing of the Perpendicular window served this

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purpose. If care is not taken in this respect the settlement of the building when new will crack the glass. Examples of panes of glass cracked, owing to settlement, are seen in many domestic buildings of the nineteenth century.



[From Ellis' Carpentry.]

FIG. 68.—TWO TYPES OF ENGLISH HALF-TIMBER CONSTRUCTION.

In modern city buildings there is the choice of other panel materials in addition to the masonry panels already referred to. Marble can be cut in thin slabs and some, but not all marbles, will resist acids in the atmosphere.¹ It should not have simulated channelling as was the Roman practice, but should be used frankly as a crystalline skin. A good example of this treatment is illustrated (Fig. 69a) in a modern building in Venice built of 2-inch slabs of Istrian marble held in position by copper clips. The advantage of bricks is that they can look the panel as well as look the course and are equally valuable as a weight bearer and weather resister (v. 10). Painted plaster in a city atmosphere has the advantage of diffusing light, but new coats of paint are frequently required and maintenance is a first factor in the designing of modern city wall surfaces. There are various tiles and terracotta products, many of them having smooth surfaces able to resist dirt, which are suitable for panel design. These products should be used frankly as flat surfaces (Fig. 69b) and should not be moulded to counterfeit stone details; they are still less suited to counterfeit rustication since they do not convey the idea of mass,

but rather the idea of a skin. An advantage of tiles is that a limited variety of permanent colours can be obtained. Large areas of tile panel can be kept clean by washing if access is provided at suitable levels from windows or balconies. The cleaning necessary to preserve the brightness of a city building should be recognised by the architect in his design.

¹ The Marble Arch, built of Carrara marble, has not resisted the London atmosphere; its surface is now covered with small cracks.



[H. B.]

FIG. 69.—HERTFORD. EXAMPLE OF ORNAMENTAL PLASTER WORK.



[H. B.]

FIG. 69a.—VENICE. MODERN BUILDING, HAVING ISTRIAN STONE PANELS.



[F. R. Y.]

FIG. 69b.—LONDON. SUMMIT HOUSE, RED LION SQUARE. RATIONAL
USE OF TERRA-COTTA. (*P. J. Westwood and Emberton.*)

10. BRICKWORK

The modern brick is really a half brick, the whole brick in the earliest times being square and thin like a tile. In material the brick has a double origin : (i.) the sun-dried mud block and (ii.) the baked tile used at first for roofing and protecting mud walls.¹ The mud block made from river mud and chopped straw and thoroughly dried by a powerful sun was used and is still used by the builders of Egypt and Mesopotamia as commonly as we now use the baked brick. An Egyptian example is given (Fig. 69c). Natural brick earths such as some of the alluvial clays contain roughly the right proportion of silica and alumina for the block to bind after being moulded and dried. The adding of chopped straw helps the binding process. *Pisé* is a modern adaptation of the old mud brick. In Mesopotamia the oldest type of brick found is plano-convex or cushion shaped, and there are both burnt and unburnt varieties. In bricks of this primitive shape "the mortar does not show in straight lines but as isolated, roughly-triangular lumps." (11) In ancient Italy and Greece the making of sun-dried bricks became skilled work. Vitruvius' chapter on bricks (I) deals entirely with the sun-dried kind. Certain earths only were used, well pounded ; and the drying process was prolonged and even regulated by law in order that the blocks might harden to the core and avoid shrinking when in position. The size of the block was adapted so that its weight was not too much for the strength of one hand. This is an important factor in design. The sizes of bricks have varied from time to time but have always returned to a size easily handled by the bricklayer.²



FIG. 69c.—EGYPTIAN MUD-BRICKS, UNPLASTERED.

The distinction between the mud block and the baked tile of the Romans

¹ The word "brick" has an obscure origin. It is first found in the fifteenth-century French as *brigue*, meaning a loaf or a broken piece. The old French word seems to be derived in some way from the Teutonic verb *brek-an*, to break.

² Vitruvius, speaking of the Greek technical terms for brick sizes, namely : Didoron (1 ft. by $\frac{1}{2}$ ft.), Pentadoron, and Tetradoron, says :—"By the word 'Doron' the Greeks mean a palm because the word

is seen in their technical terms. The mud brick was termed *later*; the tile was *testa* or *tegula*. Constructionally the difference between the two was great. Mud bricks were used right through a wall and carried weight, baked bricks were used both for carrying weight and as a facing to concrete or rubble, or as bonding courses through a concrete wall.

Now sun-dried bricks in Greece and Italy always required a rainproof coat of plaster and were generally provided with one. We have seen that the plaster coat was a strong and enduring ancient tradition and that the Greeks even plastered their limestone walls (iv. 11). When used thus over brick walls plaster doubtless helped to preserve the monolithic tradition. In Roman times the tradition of regarding brickwork, *even when baked bricks had superseded the sun-dried*, as necessarily requiring covering, obstinately persisted, and the finest brickwork was constantly hidden from view by plaster or marble.

An important exception to this tradition, however, occurs at Ostia, and this exception shows a certain freedom in Roman ideas. In that city brickwork appears to be used frankly as a fine surface to a highly-developed structural system. Brick is used for external and partition walls in the ordinary *opus testaceum*, but strongly bonded and laced with relieving arches (Fig. 70); the same bricks are used for flat arches over shop windows; brick arches carry the staircases and many of the floors are of laminated brickwork and concrete. The large-sized brick (*tegula bipedales*) capable of being cut into smaller parts by the bricklayer is thus used as a structural unit for a number of purposes (Fig. 70). A structural unit of this kind capable of being put to so diverse a use would cheapen and facilitate modern construction.

"Gauged" or rubbed brickwork is also found at Ostia on the back wall of a tomb (Fig. 71). This illustrates the recognition of brick as a finished surface, although it is possible that the area of *opus reticulatum* seen in the figure was originally covered with plaster.¹

The technical development of brickwork by Roman builders differed from the modern, in the fact that their bricks tended to decrease in size and their mortar joints to increase. The Romans recognised and preserved the tile nature of the baked brick. Roofing tiles were themselves frequently used as bricks either with or without their flanges. In the two illustrations (Fig 72) can be

signifies a gift which can be borne in the palm of the hand." The new Stockholm Town Hall is built in a brick of large size, 11 ins. \times 5½ ins. \times 4 ins., corresponding to the Norwegian medieval brick; but this is the extreme limit of size, and a smaller brick is more economical of time and labour.

¹ From a measured drawing and information supplied by Mr S. Rowland Pierce.



[H. B.]



H. B.]



[H. B.]

FIG. 70.—OSTIA. VARIOUS USES OF BRICKS.

Wall with Relieving Arches.

Brick Surface to an External Wall.

Brick Arch Carrying Stairs.

seen some brickwork from the Rostrum in the Forum, of the age of Augustus, and also some later brickwork from the Baths of Caracalla. In the latter the mortar joints are nearly as large as the bricks, and the bricks are in the nature of

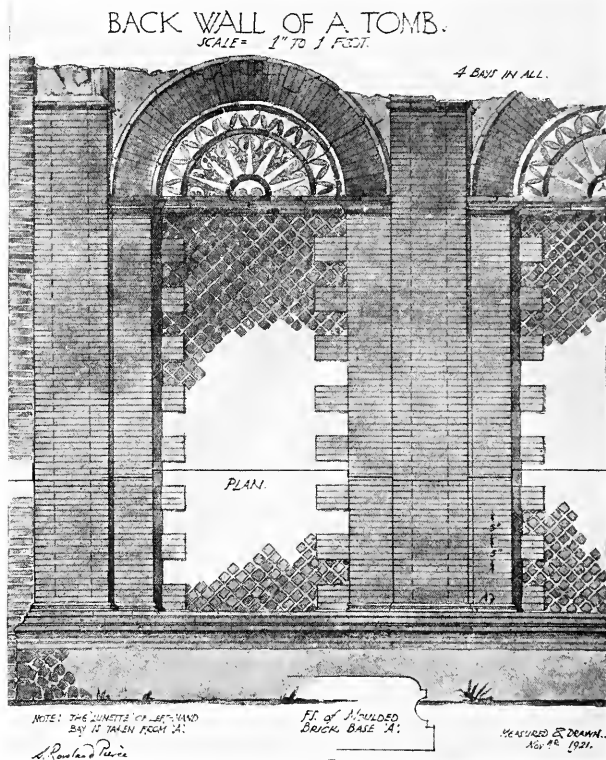


FIG. 71.—OSTIA. ROMAN RUBBED BRICKWORK. (From a drawing by S. R. Pierce.)

long flat tiles. The Romans developed the strength of their mortar and added crushed tile to the pozzolana and sand. The mortar in which the bricks were set was a separate factor from the cement in the concrete core of the walls. The use of a larger mortar joint with a stronger or more skilfully used mortar is quite

logical, but the nineteenth-century development of brickwork in England was the reverse—the stronger the mortar the narrower the joint became and the larger the brick.

The large, standard-size, Roman baked brick was called the *tegula bipedales*, roughly 1 foot 11 inches square. One of these can be seen in Fig. 72, in the right hand wall, in the third whole course from the bottom. Smaller sizes are found.¹



[Photo by Miss E. Van Diemen.]

FIG. 72.—ROMAN BRICK COURSES.

Brickwork of the Augustan Period.
Rostra in Forum.

Brickwork of the Period of Caracalla.
Baths of Caracalla.

The triangular bricks which were set with apex within the concrete were made by cutting the rectangular kind in half. The bond was generally irregular but perfectly efficient.

The Romans left brick buildings all over Europe. These, no doubt, were generally faced in the first instance with some form of plaster, which in course of time fell away and left the bricks exposed. It is probable that baked bricks were used throughout the Middle Ages from the earliest times beginning with the employment of bricks from the Roman ruins. In the Middle Ages baked bricks preserved their tile character and were known as *tegulae*, or in English “wall tiles.” Bricklayer was *tegulator* or “tiler.” Early examples of brickwork in

¹ See *Appendix, Note 5.*

England, such as Little Wenham Hall in Suffolk, still survive, dating from the thirteenth century. The medieval builders of East Anglia came to use bricks for the same reason as the Dutch, namely, a lack of building stones, but there is no evidence that bricks were imported from Holland.

The town of Hull in the fourteenth century was largely built of brick. These bricks were English made. Full details of working the corporation brickyards at Hull can be seen in the Hull Chamberlain's rolls from 1303 onwards. The term "brike" does not appear until the fifteenth century.¹ In France brick was used early in the Middle Ages and is found at Toulouse, Simorre, and Alby (Fig. 32*b*), and also in the Bourbonnais district. In this last-named district brickwork was carried to great perfection. Here is first found the diaper work in vitrified headers. (12) The Tudor school of brickwork in England appears to have been the result of an imitation of this French work by English builders after the French wars. (13) Sir John Fastolf, the original of Shakespeare's Falstaff, in his "Castle of Caister" near Yarmouth, built in brick, is said to have imitated the French chateau of Verneuill. The diaper work of this French and Tudor brickwork gives a richness of texture rather than a regular pattern effect as in the great hall at Hampton Court (Fig. 73).

The English Tudor style in brick often achieves a massive strength and horizontality more Roman than the later Elizabethan and Jacobean, and this style developed naturally in Queen Anne's reign into a true Classic. The fire-resisting properties of brickwork always commended themselves to medieval builders, and we find early brick-built flues forming a kind of core to timber houses. The great fire of London in 1666 put an end to the city-built timber house. The London Building Acts which were introduced as a result of the fire influenced town building and caused a brick style to spread over England. As a result numbers of small local brickfields were opened. This eighteenth-century English provincial architecture with its roots in the broad Tudor and its forms refined by the example of such artists as Jones and Wren is a great national achievement. Brick walls in the Georgian period were diversified by the selecting of bricks and by the use of burnt or vitrified headers (Fig. 74).

In the nineteenth century the application of machinery to brickmaking and the use of light clays insufficiently tempered caused the development of bricks, large in size and inferior in quality. British technique, as we have pointed out,

¹ Patent Rolls, 10th Oct. 1437:—"Appointment of William Weysey, 'brikemaker' . . . to search for earth suitable for making the tiles (tegules) called brike, and arrange with the landowner to dig such earth and make such tiles." See *R.I.B.A., Journ.*, 7th Dec. 1907, p. 114, note by Mr R. Nevill.

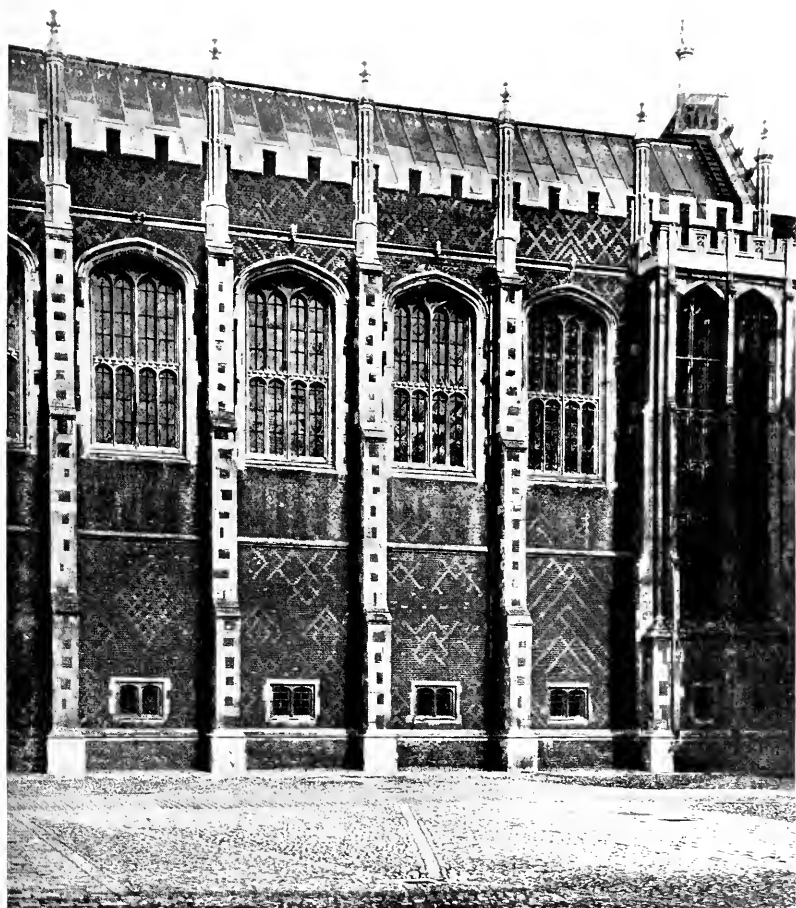


FIG. 73.—HAMPTON COURT. GREAT HALL.

took an opposite course to the Roman. The British machine-made brick increased in size and became less and less of a tile and assumed more and more the character of the mud-block artificially case hardened. The excellence of Portland cement was used in the British case to reduce the size of the mortar joint instead of (as in the Roman case) to increase it. The large-sized machine-made bricks now in common use in the north of England, set with a narrow mortar



FIG. 74.—THAME, OXFORDSHIRE. EXAMPLE OF THE USE OF VITRIFIED HEADERS.

(F. R. Y.)

joint, are not only ugly in appearance but frequently have poor weather-resisting qualities owing to lack of a good tile texture. The outer case when once penetrated by the weather flakes off and leaves the friable interior exposed. The Dutch, however, maintain their tile tradition and have kept their bricks small. But the beauty of brickwork consists in the red of the brick set in the white of the mortar, and a large joint not only improves the appearance but, as in the Roman case (Fig. 72), is structurally sound when the mortar is good.¹ In the matter of brickwork there is a connection between usefulness and a good appear-

¹ Bricks can be laid to-day with a joint as large as $\frac{3}{4}$ inch, but the time must be slower to prevent the squeezing out of the mortar.

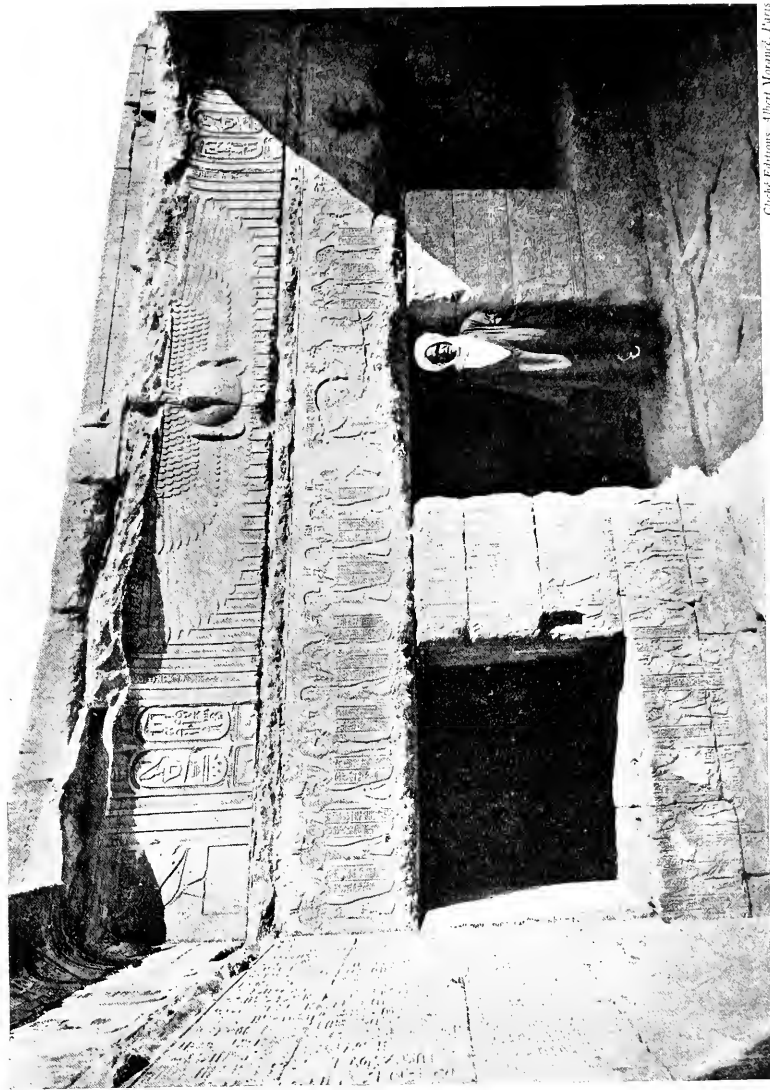


FIG. 75.—DENDEREH. GREAT TEMPLE. SHRINE OF OSIRIS.

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ance. A good tile texture is both necessary for weather resistance and presents a pleasant appearance.

II. WALL AS PICTURE GALLERY

The wall surface from earliest times has also served the purpose of a writing tablet and picture gallery. The pylons of an Egyptian temple were enormous door-posts providing suitable surfaces for inscription at the entrance (Fig. 40).¹

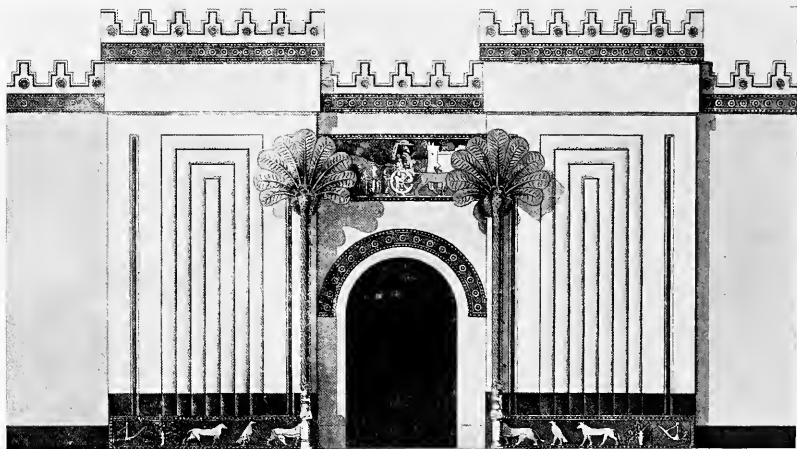
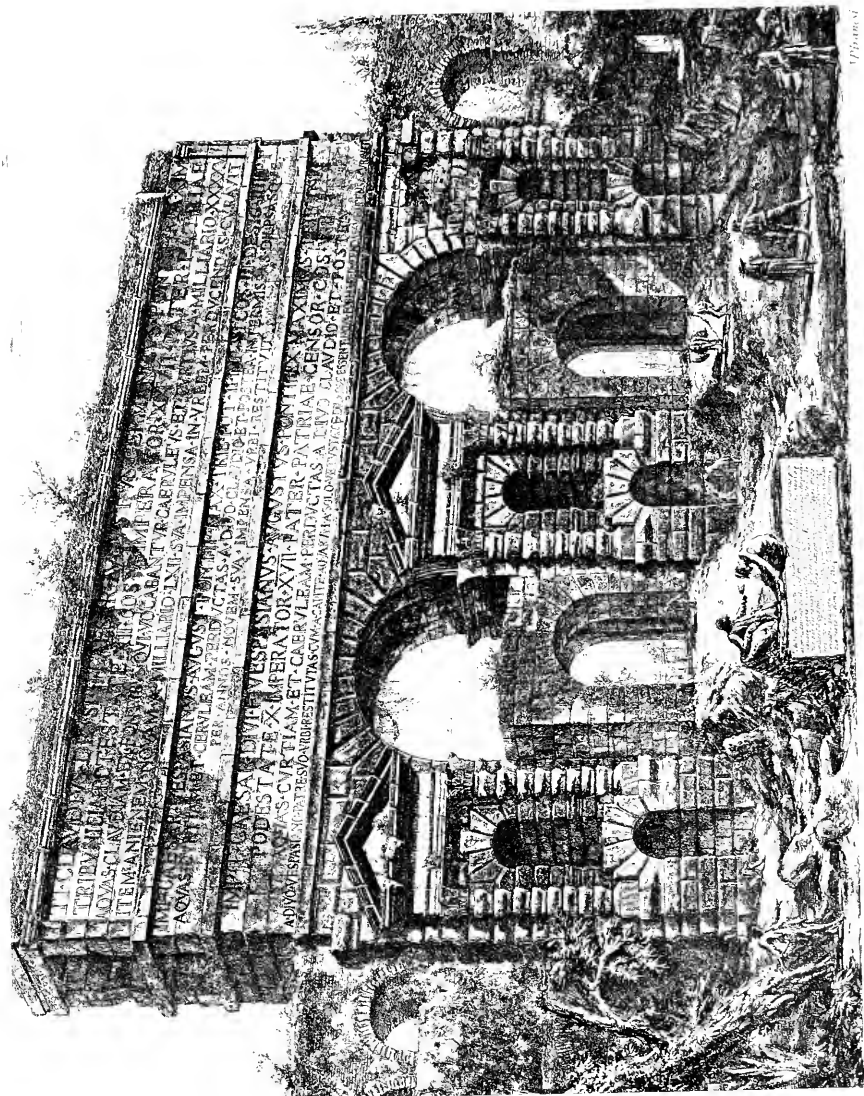


FIG. 75a.—NINEVEH. ASSYRIAN TREATMENT OF THE WALL AS A PICTURE GALLERY.
(From Victor Place.)

Monolithic or jointless building, as we have seen, gave the smooth surface necessary, and in Egypt even where joints were not hidden the figures and hieroglyphics frequently ignore them. The desire to *communicate*—to make some statement about a god or a hero at the entrance to a shrine, where people passed in and out, led by stages that can be followed, to writing, painting, and sculpture. The placing of the figures to fill in the wall spaces in a manner to please the eye—in other words “composition”—soon became an art. Beautiful compositions of combined animals, flowers, and script, were common on Egyptian walls (Fig. 75), and ornamental patterns were developed for margins. In the civilisation of

¹ For good illustrations see also Jequier, G., *L'Architecture et la Decoration dans l'ancienne Egypte*. Albert Morancé, 1924.





[H. B.]



[C. H. J.]



[H. B.]

FIG. 76a.—EXAMPLES OF LETTERING AS PART OF THE DESIGN.

Assyria walls were used for recording history and laws, and for the portrayal of the battles and hunting expeditions of kings (Fig. 75*a*). In Crete and Mycene many of the running ornaments still familiar were developed as decorative bands on walls. In Classic times with the refining of the shape of the building itself, the wall area permitted to be engraved became limited. The lintel, the frieze or the metope combined the receiving of an inscription or relief with other uses. The Greeks were the first to enlarge the letters in proportion to the height of the word above the ground. At Priene where the cella walls of temples were covered in later times with inscriptions in the Greek tongue a regular grading of letters appears to have been followed.¹ This enlarging of the letters in top lines became in Roman times, and has remained ever since, a convention. The Romans knew how to make of an inscription a fine decoration for a frieze, and their triumphal arches are characterised by the great engraved attic wall above the cornice (Fig. 76). They could make beautiful compositions out of inscribed letters alone. The Roman capital letters used to-day are stone-cut forms from the Column of Trajan, which for dignity and legibility have established their superiority over the medieval capitals derived from script upon parchment.

The first blow to the art of wall inscription and decoration was the invention of papyrus by the Egyptians. But in the twentieth century the architect has again under his hand a living activity connected with the wall surface. The modern commercial building requires inscriptions for advertisement and for the conveying of information. The motive is the old one again, namely, *communication*, the basis of all art, and as such is capable of new achievements. There is no inherent reason why the hieroglyphics of the twentieth century need be less interesting and artistic than those of the ancient world. The architect should be anxious, in a commercial building, to make lettering and pictures part of his design (Fig 76*a*).

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¹ See the Priene walls and anta in the British Museum.

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ROME. ARCH OF TITUS.



[Photograph by Hope Macey.

ROOF OF ST MARTINO ON LAKE COMO.

Chapter VI

ROOFS

1. CONTROL OF PLAN BY ROOF

WHEN a roof is added upon walls all kinds of complications are set up.

First the available lengths of roofing materials determines in any district the distances apart of walls and points of support, determines, that is to say, the amount of ground space or accommodation available. Before the invention of the truss or tie-beam, early mediterranean roofs were constructionally in the nature of flats, sometimes laid to a fall (vi. 7). In roofs of this kind the length of timbers as a limiting condition was all important and as we shall see helped to evolve the Greek temple.

The pointed roof suitable to northern climates (ii. 1) when lifted upon walls, sets up further complications. In addition to the available length of timbers there was also the thrust exercised by them upon the walls. Another factor

was the resistance to weather of the outer covering, and this determined the pitch and therefore the degree of thrust. Wind and snow also were special enemies requiring special measures. Wind necessitated an extra weight of roof-covering for the sake of stability and the staying of angles to prevent rocking; the whole building also had to resist overturning in storms. It was necessary in some, but not all structures (ii. 9), to prevent the accumulation of snow on the outside surface of the roof and for that reason a sufficient slope was required. Weight, thrust, and resistance to bending, had all to be considered. This meant that the whole disposition and arrangement, that is to say the *plan* of the building was governed by the roof and the forces to which it was exposed. In response to these forces, for example, the early Norwegian timber churches developed the strutting of their masts (Fig. 9) and the Gothic cathedrals their flying buttresses (Fig. 112), each having an obvious influence on the plan.

This control of plan by roof has helped to form the characteristic shapes met with in the history of architecture. In many cases plan-shapes are only roof shapes brought down to the ground (vi. 4).

2. PERMEABILITY OF MATERIAL

The prime use of the roof in northern and temperate climates—namely to keep out the wet—depends on the kind of covering material and on the angle at which it is waterproof. The more impervious the material the less the angle. Lead can be laid safely to a slight fall of $3\frac{1}{2}^{\circ}$ to the horizontal, pan-tiles must be laid at an angle of at least 24° , slates at 30° , stone slabs at 39° , and straw thatch at 45° .¹ The Greeks used marble tiles at an angle of about 15° (vii. 1). In the Middle Ages metal plates of all kinds and sizes² and wooden slats known as “shingles” were frequently used at a very steep pitch (vii. 3). Roofing material had a general term “*thack*” surviving to-day in thatch. In every case the pitch has played a vital part in the design of the building. A good roof is also a water-supply (vii. 2) but for this purpose—namely the collection of rain—the absorbing qualities of the material must be considered. Slates absorb less than tiles, tiles less than thatch. A roofing material should be tested for its absorption. Also the weight of the “*thack*” will influence the angle of pitch. If heavy tiles and stone slabs are hung at too steep a pitch

¹ These figures (1) are minima only. Thatch is best at an angle of 55° , pan tiles at about 35° ; ordinary tiles should be laid at 45° or 50° .

² These can be studied in the backgrounds of views and pictures in medieval illuminated manuscripts in the British Museum (see headpiece to ch. vii.).

in order to make them more waterproof they are liable to break from their pegs¹ (*See also* vi. 5).

3. ROOF CONSTRUCTION

The roof, as we have seen (vi. 1), controls the plan of a building, owing to the limit of span possible between supports. The history of building is largely a record of the effort to roof larger and ever larger floor spaces unimpeded by supports. The multiplicity of roofs of all styles and periods can be reduced to three true types as follows:—

- I. Roofs designed to be propped in the centre, the rafters thus acting as beams.
- II. Roofs not propped in the centre but exerting a “thrust” resisted by the mass of the walls alone.
- III. Roofs in which “thrust” is resolved in a true truss.

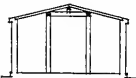
These three main roof classes corresponding to the true types are fundamental to building, and once grasped, the field of roofs becomes easier. In Fig. 77 the types are arranged in parallel columns numbered in Roman numerals, *I.*, *II.* and *III.*, each column headed by a diagram. But there are roof types intermediate in kind between the main classes, and these intermediate kinds are shown in intermediate columns. In the following paragraphs the references to Fig. 77 are in italics.

In *I.* 1 is represented the earliest and simplest of northern roofs, seen to-day in tents and in the huts of foresters and charcoal burners. (2) This roof is so simple it will serve also as a diagram. Forked posts, one at each end of the space to be enclosed, carry a ridge pole, or roof-tree, against and upon which the walls or screens of whatever kind are fixed. These screens fixed both to the ground and to the ridge-pole are really slightly loaded beams, half the load being delivered vertically to the forked posts.

This attempt to support the roof system at its centre in a dead vertical load is the characteristic of the first and most elementary type, in which “thrust” or outward pressure upon walls is not taken into consideration as a factor in design, and in which the characteristic stress is bending stress.

¹ The practical importance of adapting the weight of the *thack* to the pitch of the roof was illustrated some years ago in the case of the late Temple Moore’s beautiful church, St Wilfred’s, at Harrogate. The steep roof over the nave was first covered with heavy stone slates, very rich and varied in colour but so heavy that they had in a few years to be stripped and replaced by light tiles.

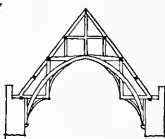
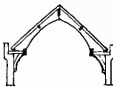
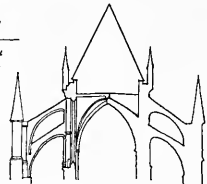
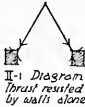
TYPE I
Principal stress
Bending.



Intermediate



TYPE II
Principal stress
compression



Intermediate



TYPE III
The true Truss. Stresses
Resolved.



FIG. 77.—ROOF CONSTRUCTION. THE THREE MAIN CLASSES OF ROOFS WITH INTERMEDIATE TYPES.

Other examples are placed beneath. *I. 2* is a Danish barn in which the ridge-piece is supported by upright posts (2) alternating with coupled raking posts shown in intermediate column. If the roof is truly fixed at the apex and held up firmly, no thrust can be exerted on the walls.

Constructively the Greek temple roof was really of this elementary kind. This is illustrated here in *I. 3*. The pitch is slight. Beams of large section carry the ridge-piece upon a furring-piece or "hypothema," as is specified by Philo for the Piraeus Arsenal (vi. 8). The rafters have three points of support, they rest upon this hypothema, also intermediately upon the cella wall, and upon the entablature at the eaves (or in the case of the Arsenal of the Piraeus intermediately upon a wooden entablature). Beams of vast section always enter into roofs of this elementary nature owing to the immense bending stress. Another true example of this form of roof was the horse-standings or army shelters (*I. 4*) built in Flanders during the war in 1915, as winter quarters for horses.

They were of great size, and consisted of a centre row of large posts with a lower row on either side corresponding with the wall positions. Ridge-piece, plates, and rafters, were formed of hop-poles lashed together, and the rafters themselves were lashed to ridge-pieces and plates. The roofs were thatch, and floors were of bricks from the ruins of Ypres. There was no thrust upon the outer rows of posts—the sagging of the hop-pole rafters on the contrary tended to pull them inwards. This example is given as a twentieth-century instance (adaptable at any time in farm building) of this simplest type of roof; it well illustrates the characteristic stress of the type, namely, bending stress. The ends of beams require attention in this type of roof; they are liable to drag off the walls or else to rot and shear through.

There exists also a series of antique structures of the "megaron" or hall type having a central row of columns in order to prop the roof. This type at

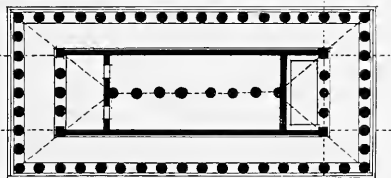


FIG. 78.—PAESTUM. "BASILICA" PLAN, AND VIEW OF CENTRAL ROW OF COLUMNS.

vi. 3. Theory and Elements of Architecture

its highest is represented by a Greek Doric building known as the "basilica," at Paestum (Fig. 78), having a central row of columns which obviously supported the roof upon this elementary principle.¹ From the central roof-support in this type of building there followed logically a centre column on the front.

Other examples of this structural principle are found in the group of English Perpendicular roofs known as bearer roofs of which Stoke by Nayland church is given as an example (I. 5.) (see also Figs. 101 and 101*a*). Sometimes the bearer beams are cambered in order to lift the rafters at the centre; sometimes a furring-piece is inserted resembling the *hypothema* in Philo's specification (vi. 8).

In this primitive form of roof it is obvious that the three points of support, namely, the central ridge-piece or roof-tree and the tops of the two walls which we now speak of as the wall-plates, were of special importance. It is natural to find, therefore, that the ends of ridge-pieces and wall-plates were selected for special decoration in primitive times. In Greece the central acroterion marked the end of the ridge-piece (Fig. 86). In the Etruscan temple the gorgoneion²

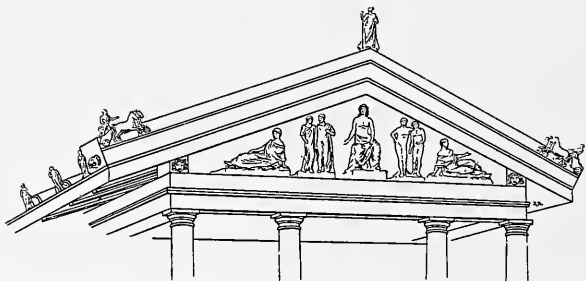


FIG. 78*a*.—SKETCH OF THE EARLIER TEMPLE AT FALERII, SHOWING GORGONEION ON EACH OF THE BEAM-ENDS. (Taylor and Bradshaw.)

occurred in positions corresponding to the ends of the beams or wall-plates (Fig. 78*a*). In the Scandinavian timber churches the end of the ridge-piece is marked with a characteristic dragon (Fig. 79 and also Fig 11.) These ornaments had doubtless in addition a magical protective value³ but it was the key members

¹ Examples of this type of structure are also found at Selenus in Sicily, at Neandria, Sparta, and Locri. (See Appendix to *Tempio di Giove Olimpico in Agrigentum*, 1922, by Professor Pace and S. Rowland Pierce.)

² Taylor, M., and Bradshaw, H. C., "Architectural Terra-cottas from two temples at Falerii Veteres," *Papers of Brit. School at Rome*, vol. viii., 1916, pp. 17 and 25.

³ See also E. Strong, *Journal of Roman Studies*, 1914, p. 164.

in the construction that were instinctively conceived of as requiring special protection both from material and spiritual dangers.

The second true type is illustrated in column *II.*; the diagram at the head, (*II. 1*) shows the nature of the stresses. The characteristic stress here is compression. A pair of roof members, such as coupled rafters, have their feet fixed only to the wall-plate and are not prevented by a tie-beam from spreading. They are themselves in compression, and exert upon the wall an inclined thrust which can be resolved into vertical and horizontal components. The mass of the wall alone offers resistance and maintains equilibrium. This type, therefore, requires excessively thick walls to take up the thrust produced and in modern practice is confined to the smallest cottages and sheds. But in the Middle Ages the English arch-braced roof without collars, as St Peter's Mancroft Norwich (*II. 3*) is really a roof of this type relying solely upon wall resistance. Also, in the stone vaulted Gothic churches, if we consider the two halves of the pointed arch as two roof members, the stresses set up can be very roughly compared for our present purpose.¹ In *II. 2* an illustration of a thirteenth-century cathedral vault shows how equilibrium is maintained by balancing the inclined thrust of the vault against the resistance of the mass of walls plus buttresses. In order to avoid too great a thickness of wall the effective bearings were increased by means of buttresses which, as we have seen (*v. 7*), are only sections of wall turned at right angles to the line of thrust. The vertical load, instrument of stability, was increased by the pinnacles which were purposely built on the top of wall and of the buttresses or, in the case of Wren's St Paul's, by the attic wall (*iv. 3* and *Fig. 39*).

In this type, in spite of careful balancing of vault against wall and buttress, failures have often occurred. In the case of St Giovanni e Paolo, a Gothic Church in Venice, wood tie-beams have been inserted across the nave in order to pick up the thrust, and these, to northern eyes, have destroyed the whole rationale

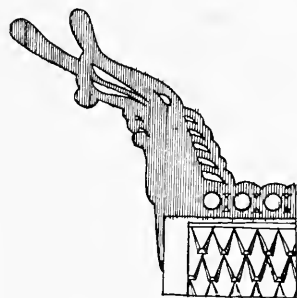


FIG. 79.—BORGUND CHURCH, NORWAY.
DRAGON CARVED AT THE ENDS OF
THE RIDGE-PIECE.

¹ The methods of computing stresses in stone ribs and in wood struts are of course quite different, likewise the methods of computing arched members and straight members; but the effects upon a plan system of stone and of wood members transmitting analogous pressures can be compared.

vi. 3. Theory and Elements of Architecture

of the design (Fig. 80). Many other churches by the Italian Gothic builders, who seem not to have understood buttresses, are equipped with wood tie-beams.

Type *III.* is the trussed roof in which the horizontal thrust upon the walls is counteracted by a pull upon a tie-beam. Here the tie-beam is recognised as an alternative to the buttress. Now the simplest truss is a triangle, *III. 1.* The triangle is the only assemblage of members which when pin-jointed is rigid and unalterable. A true truss is one in which all the members are in direct stress and, however complicated, is built up out of a series of triangles.

Thus a king-post roof is a true truss but a queen-post roof (Fig. 81) is not a true truss.

Vitruvius' roof (*III. 2*) formed of tie-beam (*transtrum*), post (*columna*), and struts (*capreoli*)—(see also Fig. 95)—which he recommends for use "if the roof be of large span" is really a simple form of king-post truss and its appearance



FIG. 80.—VENICE. ST GIOVANNI E PAOLO. INTERIOR SHOWING WOOD TIE-BEAMS.

marks the beginning of modern carpentry (vi. 9). It is probable that the Roman carpenters realised that the transtrum or tie-beam was in tension since they designed roofs to early Christian basilicas having king-posts pinned beneath the tie-beams (Fig. 95*b*). But it would seem that the English medieval builders did not realise

the nature of the stress in the tie-beam. In *III. 3* is illustrated the roof of Haughley church, Suffolk. In this the joint-pieces stiffen the members but play no real part in carrying load, and the tie-beam scarcely looks like a member designed for tension, in shape more resembling the bearer-beam in *I. 5*.

The French Gothic builders, however, fully realised the true nature of the tie-beam and used it to much better effect than did the English. The roof of St Ouen, Rouen, above the vault, dating from the fourteenth century is represented in *III. 4*. The tie-beam is chamfered and the three posts are clamped over it. Tie-beam and posts are all recognised to be in tension and the side posts are actually cut away in the centre for lightness (Fig. 99).

In the building of new churches in France in the Middle Ages the roof was in some cases built before the vault in order to stiffen the whole building while the vault was in process of being built beneath (p. 217).

In *III. 5* and *III. 6* are illustrated the logical use of the steel rod for resisting tension. Theoretically, each of these steel roofs rests upon its supports without exerting any thrust; in *III. 6* the support is the ground and the whole principal becomes a roof truss.

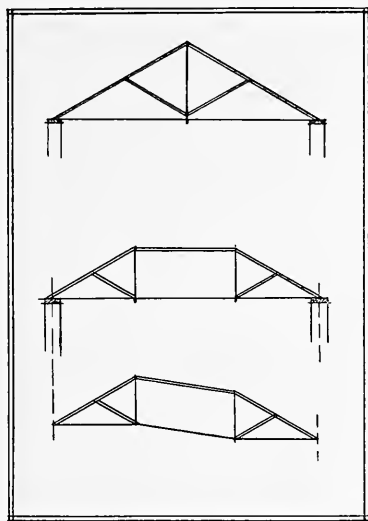


FIG. 81.—KING-POST AND QUEEN-POST ROOF TRUSSES COMPARED.

Interesting roofs, intermediate between the true types, are given in the two intermediate columns. In the intermediate column, between classes *I.* and *II.*, is shown first the Irish Oratory roof, formed of stones corbelled inwards until they meet at the ridge. This construction is megalithic in origin and was adapted by Christian missionaries in a land where there were no Roman building traditions. Stability is had by a multiplicity of horizontal bearings without mortar, able to resist sliding through friction. In the Danish barn, next below it, already referred to, is shown a form of fork found in buildings of *I.* type.

Raking post supports are placed alternately with the single post supports as in *I. 2*, in order to give stability to the whole building against overturning by wind (2).

The English roof on crucks, next below, can be viewed as an example of type *II.*, in which the earth takes up the thrust of the crucks; but it belongs more truly to type *I.* by reason of the *intention in design* to carry the roof by a central support (*see* Figs. 4 and 102). The York Guildhall roof is shown in this intermediate column owing to the obvious intention to support the principal rafters as bearers by means of posts and brackets.¹

In the intermediate column, between classes *II.* and *III.*, occurs first the roof of the twelfth-century wooden Norwegian churches such as Borgund, Gol, and Stedje. Of these the roof at Gol is illustrated. This roof is part of a highly developed wood structure derived from shipbuilding (ii. 9 and Fig. 9).

Next below, come the family of roofs caused directly or indirectly by the inconveniences of the tie-beam. The tie-beam however admirable, theoretically, obstructs the internal space, and the English medieval carpenters, in order to gain height in churches and halls, evolved the series of beautiful and elaborate roofs of the scissors truss, shown in the Monks Eleigh example, and hammer-beam types. None of these are true trusses. In all of them the thrust is partly resolved by collars and partly carried down and distributed upon the surface of the wall. In this type the greatest achievement is Westminster Hall (shown next below Monks Eleigh) combining all the medieval technical methods of stiffening and distributing, and spanning nearly 69 feet in the clear. (*See also* ii. 9 and vi. 10.)

To sum up, all roof types of whatever kind have their own advantages and disadvantages. Type *I.* (the bearer-beam type) depends upon the dimensions of single timbers available in order to cover the span, and we shall see that this fact influenced Greek temple plans (vi. 8). Its disadvantage is that it requires intermediate supports, yet its structural simplicity gives it permanence and a true monumentality. Type *II.* (the buttress type) requires either excessively thick walls or else a vast masonry abutment and the disposing of walls to meet thrusts. It can give on the inside of a building a fine unimpeded space and a great height, but the necessary abutment system on the outside, as in a Gothic cathedral, requires ceaseless attention and upkeep. Type *III.* (the tie-beam type) is undoubtedly the most scientific, yet it restricts head room and diminishes the apparent height of an interior. We shall see that the different attitude

¹ *See* Fig. 146. Compare also the restoration by the Office of Works of the Norman hall at Westminster (ii. 9 and Fig. 146).

taken to the tie-beam by English and French carpenters considerably influenced medieval building (vi. 10).

4. ROOF SHAPES

We have seen (ii. 1) that climate tends to determine essential shapes, also that the roof or inclined plane varies in steepness or pitch and this variation is a factor in the origin of styles. Parent shapes as different as the Greek temple and the English cottage on crucks are variations obviously due to climate. To these we must add the curved shapes—dome, semi-dome, and barrel vault—which have risen from a number of coincident factors, among which are protection against climatic extremes (iii. 5).

The parent northern shape—the pointed or high-pitched roof at first enclosed only a small space. Its shape was an upright wedge, and any addition to the accommodation available was to be had by lengthening the gable (Fig. 94) or by adding separate new buildings similar in span. But the inventiveness of wrights¹ on the one hand and of stone-workers on the other made possible an ever larger span and at length a variety of shapes.

These shapes once created by active craftsmen came to interest all kinds of artists by their character and vitality,² so that they quickly took on an independent or æsthetic life of their own.

Historically, the form value of the roof is as noticeable as the construction. It is possible in England to trace the rise of the roof from the moderately sloped Romanesque to the fashionable peak set by French Gothic, to trace its fall again in English Perpendicular, its rise in response to a Dutch fashion in the Jacobean, its fall again in the Anglo-Italian of the eighteenth century, and rise again in the nineteenth century (vii. 8). It is possible on the other hand, in France, to observe a constant intelligent maintaining of the high roof for artistic purposes (vii. 7).

Now the design value of *wall* may be that of surface only, of something in two dimensions; *but wall plus roof*, involves three dimensions, it is something occupying cubic space, and having depth. The masses or cubes given us by roof upon wall, are units of design. Wedge, pyramid, cone, cupola placed upon square, oblong, and cylinder, make up the general scale. The architect has to

¹ The *wright* was the general term for the worker in wood, of whom many trades existed: in medieval Latin—*carpentarius*. (2)

² Note the use made of them by medieval painters for purposes of composition in the background of pictures. See headpiece to ch. vii.

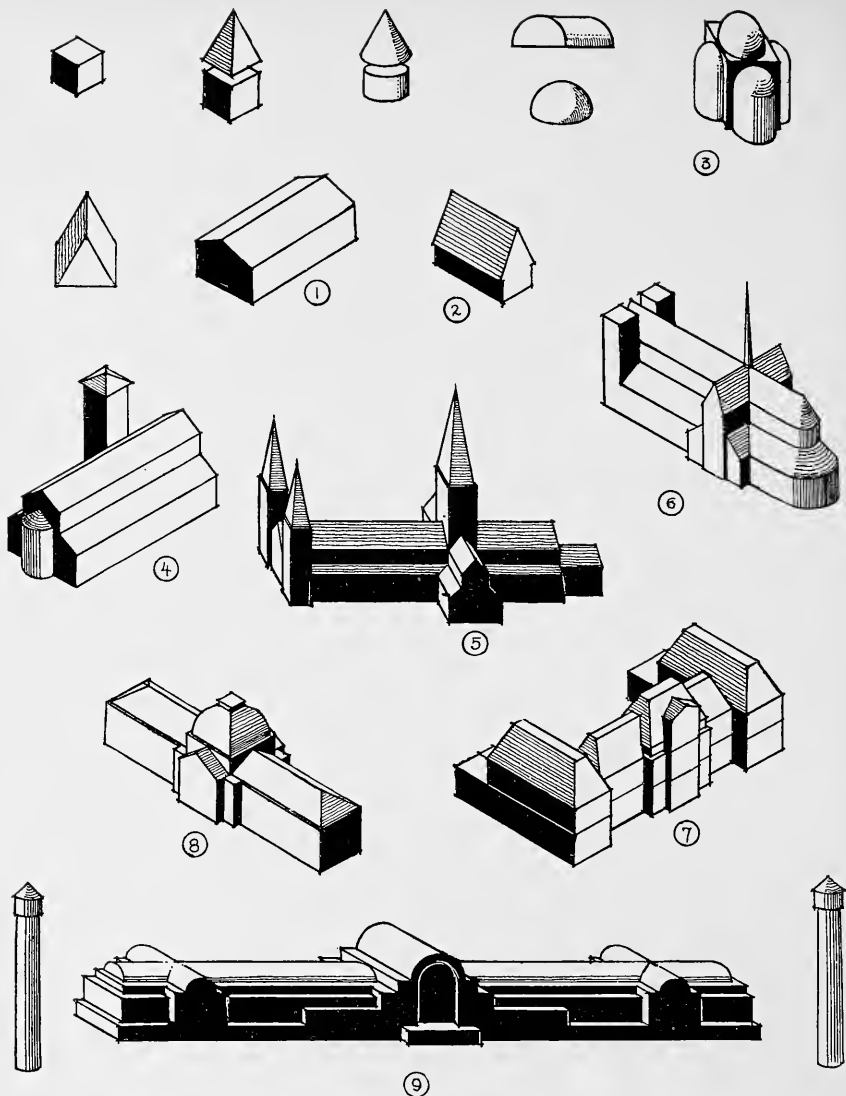


FIG. 82.—ELEMENTARY PLASTIC UNITS AND SOME BUILDINGS COMPOSED OUT OF THEM.

combine, relate, and set in contrast these units, and the combinations are capable of infinite variety.

In Fig. 82 are given some illustrations of these elementary units and of some buildings compounded of them. The shape (1) is that produced by just sufficiently sloping two halves or "flaps" of a roof covering an oblong, in order to shed a light rainfall. It became a parent form, first common in the Classic temple, and then in many later structures (vi. 8). The shape (2) is a steep wedge upon a low rectangle. The roof here is able to throw off snow and severe rains. The resulting shape is as familiar to us as (1), yet its character is quite different; here the roof is the dominant note, the rectangle beneath it being secondary, whereas in (1) the rectangle is the dominant and the roof serves rather to complete it and set it off. The spheres and the cylinders, with their segments, the dome and apse, or "barrel" are a group of shapes that will require special consideration in another part. Their curves when brought in contact with rectangles give the most marked contrasts and can be used to produce the finest combinations in architecture. The shape (3) is a combination of rectangle with domes and half-cylinders; it is a church form early developed by a people having traditions of dome building from the East. As a type it was developed to its most elaborate by the Armenian and Byzantine builders. Combinations of half-cylinders with rectangles are often employed in modern engineering construction in railway stations and exhibition buildings. Shape (4) is the Crystal Palace formed of half cylinders resting upon stepped rectangular masses, and set off by a vertical cylinder at each end.

If to type (1) passages or aisles are added at each side, and a half cylinder added at the end, and a vertical oblong bell tower set at the side, then shape (4) is produced—an early Christian or "basilican" church type.

Shapes (5) and (6) are multiplications of shape (2). That on the left is a typical English cathedral, that on the right a typical French. They are different in plastic character. The huge roof of the French church dwarfs the western towers; the cylindrical French apse contrasts with the English square and stepped east-end. The French church is a single well-buttressed hall, all the parts dominated by the roof. The transepts are shallow and the crossing is marked only by a *flèche*. The English shape is lower and longer. The parts have more individuality; the building is a group of halls rather than a single hall. The roof is less emphasised and the dominating feature, giving unity to the whole, is the tall central tower. The long transepts give a truer cruciform plan than the French. This art of the group dominated by a tall vertical mass is the special English

contribution ; it is analysed more fully later (vii. 9), and other characteristic English shapes and groups of shapes due to combinations of roofs and towers are examined. The steeple or pyramid is a pointed form shared by both mediterranean and northern builders. In the south the pyramid was evolved not for the sake of resisting weather but as a sacred shape suitable to mark tombs. The Greek pyramidal roof over the Mausoleum of Halicarnassus and a few examples of Roman pyramids can be cited in addition to the Egyptian. The Gothic church combines this monumental or non-utilitarian employment of the pointed shape with the utilitarian or weather-resisting.

In (7) the Chateau de Maisons, a French seventeenth-century Renaissance building is shown reduced to its elements. In this form it might be either Classic or Gothic, and presents nothing but a harmonious disposition of shapes, the grouping skilfully emphasised by means of the tall roofs. A glance at the roofs reveals the plan of the whole building. Roof and rectangle are equally important in the composition.

In (8) the elements of the main block of the École Militaire in Paris give an example of the use of a central shape dominating two wings. The roofs here are not conspicuous, the two important factors are the dome and the rectangles.

All these buildings then are compositions or placings together of useful and convenient shapes. The art lies in the composing. And viewed coldly and objectively the most moving work of architecture, stripped of its associations, can be reduced to one or other of such simple shapes, or groups of shapes, disposed in an adequate light. The architect should learn to think in them and to see their arrangements and re-arrangements, in all the buildings he studies. More than that ; when he is himself solving a problem in design he should, even in the intricacies of modern special requirements, carry the essential plastic units of his final group always in his mind.

Many modern buildings when they are fully analysed can be reduced to quite simple groups. A terminal railway station is an end or stop to a gigantic passage-way. A theatre is a tall rectangular stage block with auditorium butted against its lower part. The hospital is a series of separate rectangles branching out from an administrative centre and arranged to catch the maximum of sunlight. A modern public library consists of a tall stack-room for the books, a central administration, and various reading rooms. In all such cases the simple plan pattern should lead straight to the simple roof pattern ; and the roof in its turn will express the plan. A fine building is finer and more interesting if its plan

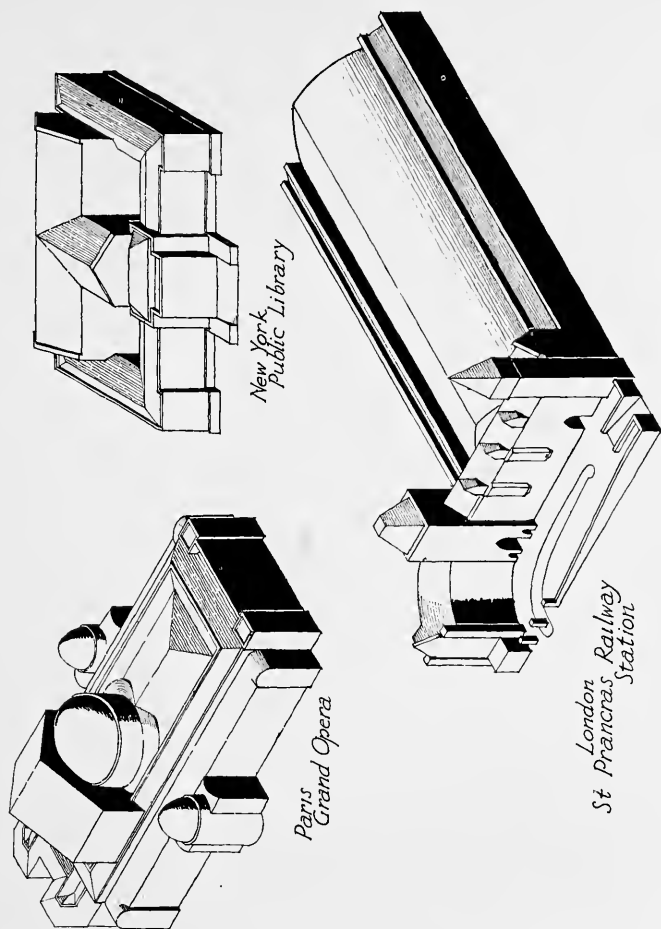


FIG. 83.—NEW YORK PUBLIC LIBRARY, ST. PANCRAS RAILWAY STATION, AND GARNIER'S OPERA HOUSE, PARIS,
REDUCED TO THEIR PLASTIC ELEMENTS.

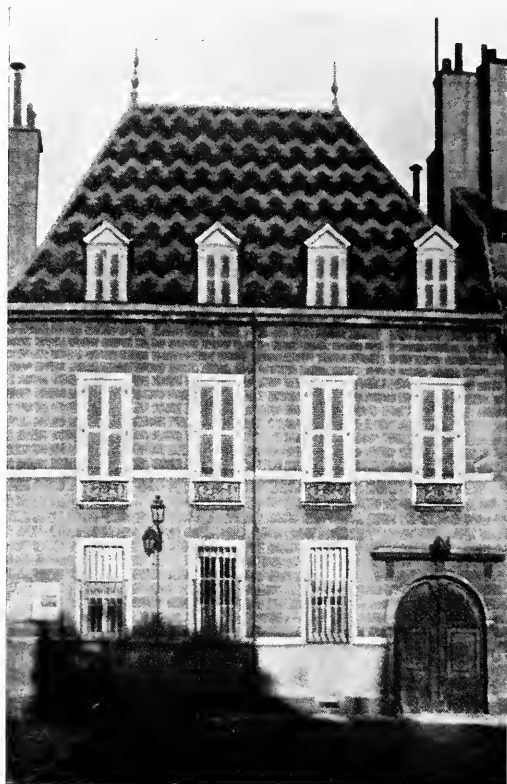
can be read directly from its masses. In Fig. 83 a theatre, library, and railway station, are illustrated reduced to their elements from actual examples.

5. DECORATION AND TEXTURE

Such was the importance of the roof in northern climates that when orna-

ment came about it was naturally applied to the roof as the most conspicuous and beneficent part of the building (ii. 1). In early nordic literature, the roof is often spoken of in an epic manner and the ornament remarked upon.¹ We have already noted the Norwegian dragons, the Greek acroteria, and the Etruscan gorgoneion (vi. 3) which protected and ornamented special parts of the roof.

The instinct to make much of a conspicuous roof slope is a sound one but requires thought. The roof as a plain surface and shape is most valuable for the purpose of unifying an elaborate wall or buttress treatment below it (vii. 7), but cannot serve this purpose if it is itself highly ornate. Where the wall treatment is simple and the roof conspicuous its surface can be given an interest as in the



[H. B.]

FIG. 84.—DIJON. HOUSE IN THE RUE DE LA PREFECTURE.

¹ Examples are given in the note on p. 19.



FIG. 85.—LEAD ORNAMENT UPON ROOFS.

Above—Paris, Hotel de Soubise Roof.

Below—Versailles, Early Palace Roof.

patterned roofs of Dijon and other Burgundian towns. Here the dark velvet surface of the common tiles laid at a steep pitch are enlivened by a pattern in glossy tiles (Fig. 84). This Burgundian roof tradition is a very fine one, but both in medieval and Renaissance times has been accompanied by a corresponding restraint in wall treatment. The church of St Benigne at Dijon is a good medieval example of this tradition. Its value is felt, in city vistas and distant views, where the tall roofs are conspicuous; often they are invisible from the street below (Fig. 160a).

Another method of deliberate roof decoration is that of applied lead ornament in the form of bands and running patterns. Here again restraint is necessary if the roof is to rule the whole mass, and the best lead ornament of this kind is in the nature of an emphasising of edges and margins, upon a plain slate surface. For this reason the upper example in our illustration (Fig. 85) is finer architecture than the lower.

An object in roof decoration is the breaking of hard, monotonous outlines seen against the sky. We shall see (vii. 1) that the peculiar construction of Greek roofing tiles caused the need for a series of stops or abutments at the eaves for each row of tiles which when emphasised and decorated became the ornaments known as *antefixæ*. The *antefixæ* sometimes, as at Phigaleia, took the place in the cornice of the cymatium mould along the flank of a temple. Like all true elements in architecture these were the result partly of a constructive and partly of an artistic sense. The *antefixæ* came to have corresponding ornaments along the ridge (Fig. 86). In the Greek colonial architecture in Sicily where the terra-cotta tile was used for the most monumental buildings¹ and was not superseded by the marble tile, the *antefixæ* in coloured earthenware were enlarged and became part of an elaborate system of coloured eaves decoration, which crowned an entablature of limestone. This is also to be observed in Olympia in the Treasury of Gela (Fig. 86a).

The later Classic lions' heads and the medieval gargoyles and waterspouts are also a development of the same instinct in design. In Renaissance times the vertical lines of the columns were sometimes carried up above the cornice in the shape of statues and these served the purpose of breaking an outline against the sky as upon Bernini's colonnades to St Peter's, but they do not truly correspond to acroteria in that they are not developments of roof lines downwards but rather of column lines upwards. In modern domestic roof construction, however, a real parallel exists which could be elaborated. The line of tiles forming a hip to a

¹ Hulot and Fougères, *Selinonte*, 1910, p. 227.

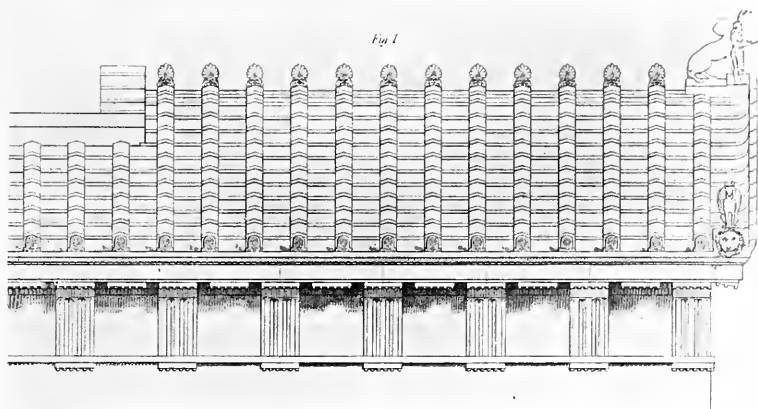


FIG. 86.—AEGINA. ANTEFIXE ON RIDGE AND EAVES OF TEMPLE. (Cockerell.)

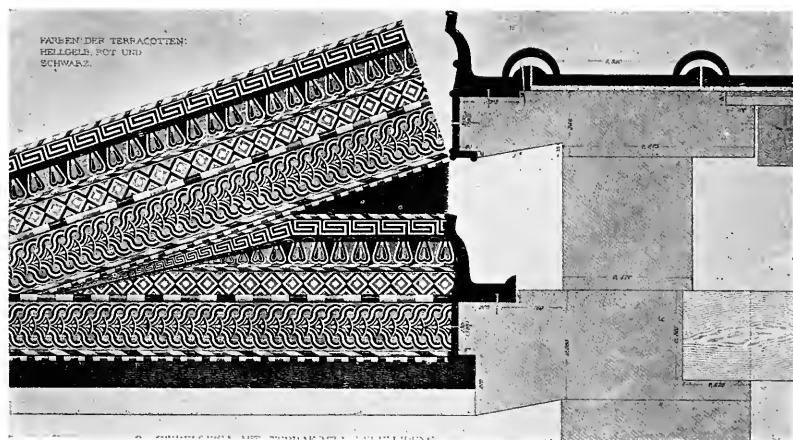


FIG. 86a.—OLYMPIA. TERRA-COTTA CORNICE TO THE TREASURY OF GELA. (Curtius & Adler.)

tiled roof is frequently held up by an iron bracket or hip hook attached to the foot of the hip rafter and turned up to hold the lowest tile in place which then supports the whole line (Fig. 87). This bracket is frequently left projecting without decoration, or is given a simple twist. The Greeks would have made it into a true point of ornament.

Roof colour and texture is always a legitimate object in design. The plain contrast of roof to walls in surface feeling, is one of the first and simplest artifices of design. In the matter of colour the architect must work with a delayed palette, time alone can give the real tones. With tiles as with bricks (v. 10) a good material thoroughly vitrified must be used if the surface is to endure and weather to a rich colour.

Roof texture can be had by emphasising joints, and in the first instance came about quite simply in the machinery of weather-proofing. The vertical joints caused by butting a series of earthenware pans or stone slabs together upon a mediterranean roof-flap required protection. This protection could take the form of merely weathering the surface of the slab so as to draw the water away from the joints or of placing "cover tiles" over vertical joints in the Greek manner (vii. 1) or the Roman manner (vii. 2). The vertical lines of these "cover tiles" give the texture to a Classic roof (*see* Fig. 86) apart from questions of ornament.¹

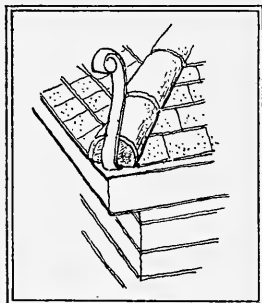


FIG. 87.—HIP HOOK.

Slating differs from early tiling in overlapping vertical as well as horizontal joints, and for this purpose slabs of stone must be of equal thickness but need not be of equal size. In the Alps many houses to-day are roofed with thin bits of shale of all sizes and shapes, and a very interesting texture is the result (*see* headpiece to this chapter). Rough stone slates have always more texture and look better than the monotonous standardised kind.

¹ Beauty of texture and emphasis of shape in roof design do not commonly go together. It is noticeable that where a type of building has reached a high state of formal refinement the roof as a surface has often (though not always) been simplified. In the Renaissance palace the roof has frequently been reduced to a lead flat, in the Gothic cathedral to a lead slope without surface interest. On the other hand, in the cottage or the farmhouse the roof with its soft tile textures or variegated stone slating has become a thing of beauty without any artifice in design.

6. THE THREE FACTORS IN ROOF DESIGN

In the study of roofs we can now distinguish three great formative factors.
(i) Construction and permeability of roof with consequent effect on the placing of walls. (ii) Accommodation required in the building for a given purpose. (iii) The kind of outside shape or *image* delighted in and preferred above other shapes. These three factors will be considered throughout the following narrative.

7. EARLY FLAT ROOFS AND THEIR INFLUENCE ON PLANNING

In the East to-day, wherever timber is to be had, a common roof is made by first laying logs or beams across from wall to wall of a mud-brick building. The

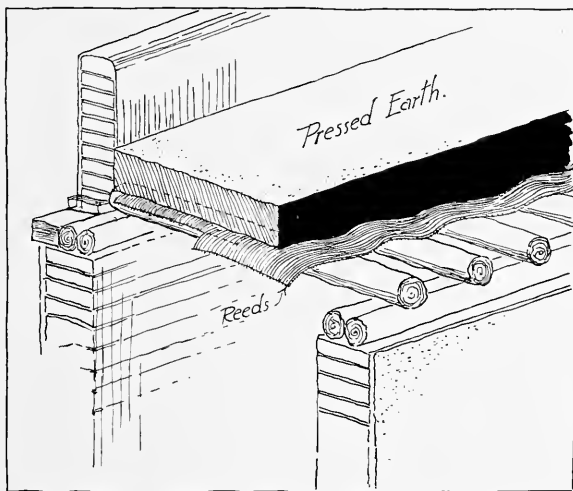


FIG. 88.—SIMPLE EASTERN BEARER ROOF, COMMON IN ALL PERIODS.

logs are spaced near together, covered with reeds or mats, and earth is then thrown upon the top to a considerable depth (Fig. 88) and rammed and consolidated.¹ Now, in dry climates, this roof is probably as old as building itself and a narrative

¹ A common custom is to roll the earth with a roller formed of the fragment of a column. (See Schliemann's description of his own house, in *Tiryns*, ch. v., The Roof and Roofing, p. 272.)

of roof development can well begin with it as a starting-point. The reeds or mats are really a kind of centering which enables the earth to be rammed and thus arch itself over from beam to beam within its own thickness, but the beams or logs carry the load and are in bending stress only. The depth of earth protects from the sun's rays, an essential requirement (ii. 1), and if rain has to be countered

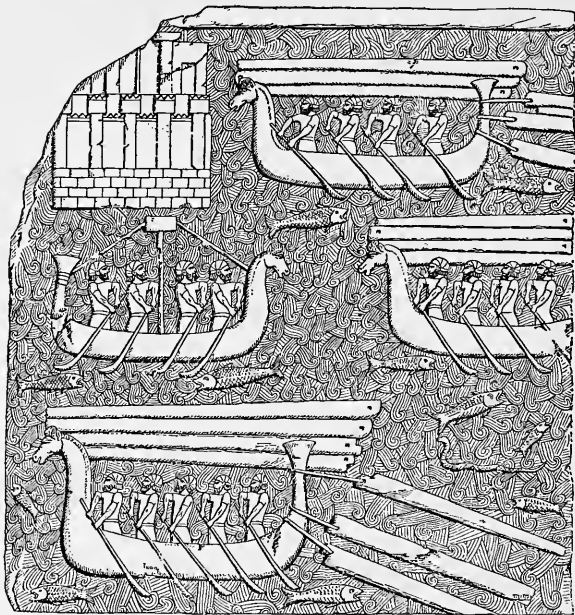


FIG. 88a.—BRINGING CEDAR LOGS FROM TYRE IN ASSYRIAN SHIPS FOR THE PALACE OF SARGON.

the earth can be laid to a slight fall ; in Mesopotamia bitumen can be used to-day as a natural asphalt, exactly as it was used in the earliest times. Rooms can be added in any direction by extending roof supports. This type of roof, however, depended on the nature of the timber for its development. We have seen that the great sources of timber in the ancient world were Lebanon, Taurus, and Amanus (Fig. 6). Upon these sources of cedar the great builders of Assyria (Fig. 88a), of Syria, Egypt, and the Ægean all drew largely for their monumental

buildings at different periods, and as we shall presently see (vi. 8) carried roof structure as far as the bending strength of cedar could serve them and no further. The common kinds of timber were pine, cypress, poplar, juniper, got from local sources. It was when the main timber supplies began to fail that the arch, which had always been known even from Sumerian times, came to be used generally instead of timber and to change the common eastern mediterranean roof from "bearer" type to domical or vaulted (iii. 5 and 6). But before the period of deforestation, and to a less degree in subsequent periods also, the common eastern roof was of the kind we have described—in carpentry nothing but the simplest kind of bearer beam. Its effect on planning can be read in nearly all the early styles. Where palm trunks—a poor timber—had to be used walls were brought closer together in consequence. Where fine masonry was plentiful the same "bearer" principle could also be carried out in stone by placing near together the points of support. Hittite, Assyrian, Minoan, Mycenaean, Greek, and Egyptian plans all show the long passage-shaped cell, either as apartment or whole structures, and for large and small spans. This type of planning is a direct result of the bearer roof. Assyrian and Minoan examples¹ are shown in Fig. 89.

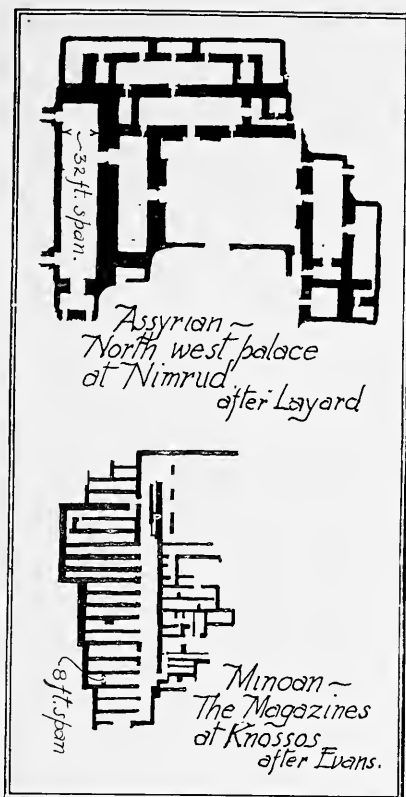


FIG. 89.—PLAN OF A LARGE SPAN BUILDING (ASSYRIAN) AND A SMALL SPAN BUILDING (MINOAN) SHOWING LONG OBLONG CELLS.

¹ The spans shown in Fig. 89 are approximate only. For scale dimensions see Layard's *Nineveh and its Remains*, 1849, vol. i., plan 3, and (Knossos) *Annual of the British School at Athens*, vi., plate 13.

vi. 7. Theory and Elements of Architecture

In Egypt the fine supply of stone (iii. 1) soon led to the placing of masonry slabs across a short safe span between parallel walls or parallel rows of stone piers (Fig. 89*a*). When large areas had to be roofed in Egypt, for purposes of ceremonial or of assembly, the stone-slab roof was extended simply by multiplying

supports. Thus both the colonnaded hall and the long oblong room characteristic of Egyptian temples arise from the same structural method. Both can be studied in the plan of the temple at Abydos (Fig. 37) and in the illustration of temple at Thebes (Fig. 89*b*). The method can be seen also shaping Egyptian domestic plans. In the Egyptian temple the successive courts and cells decreased in height, the ceiling of each becoming lower as it increased in sanctity and secrecy. Thus the flat roofs were successively stepped down, and this stepping gives the plastic character to the Egyptian temple (Fig. 89*b*).



(Reproduced by Permission of Messrs Newton & Co.)

FIG. 89*a*.—EGYPTIAN LINTEL CONSTRUCTION, TEMPLE OF KHAFRE.

The very low rainfall in Egypt (ii. 1) enabled flat roofs to remain flat; but if we follow the same roof type northwards to Crete, Mycene, and Athens we can see the climate acting progressively upon the shape of the building. The discovery of the earthenware tablets at Knossos in Crete (3) revealed the complete elevation of the Cretan town house. In Crete at certain seasons heavy rains fall. The houses were of two stories, sometimes with an attic,¹ and show that a slight fall was in some cases given to the roofs² (Fig. 90). The Cretans used a lime cement for their drains, and upon their roofs used a clay cement common

¹ The attic, as seen in Fig. 90 (lower house), is still a building tradition in Crete, and can be seen in houses in Candia.

² Sir Arthur Evans describing one of these elevations says: "It will be seen that the 'attic' . . . has a decided slope, doubtless in order to shed the rainwater, and the inclination visible in the roof of the two wings of the house must have had a similar object. As a rule, however, the house roofs are represented level." (3)

on the island and still used. In a part of the plan of the palace of Knossos (illustrated in Fig. 89) a series of long passage-like chambers used for store-rooms or magazines is specially noticeable showing the influence of the flat-roof type we have analysed. The whole plan of the palace, indeed, consists of an aggregation of long oblong cells often having courts divided by columns, all wonderfully contrived and with excellent communications but with no strong group shape like the Egyptian temple.

Farther north on the main land of Greece the fortress palaces of Mycene,

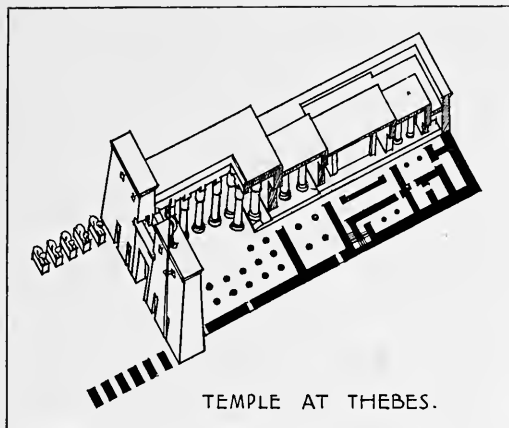


FIG. 89b.—EGYPTIAN PLAN AND EGYPTIAN ROOF.
(After Choisy.)

Argos, and Tiryns had short but sharp winter conditions to encounter, and the Mycenaean plans in consequence, have well-defined hearths. The roofs were structurally of the same "bearer" type formed probably by logs or poles placed side by side over a short safe span. A common ornament in Mycenaean and Cretan building is that of running circles which inevitably suggest the projecting ends of logs, and upon these logs Schliemann assumed that rammed clay was used for water-proofing, on the principle illustrated in Fig. 88. "Not a single tile of baked clay was found anywhere in the palace [of Tiryns], nor was there on the site any trace of a

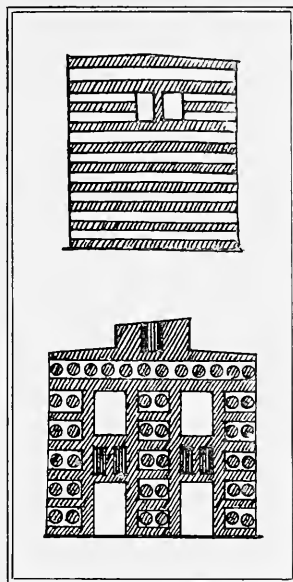


FIG. 90.—ELEVATION OF MINOAN
HOUSES SHOWING ROOFS LAID TO
A FALL. (After Evans.)

lime plaster suitable to roofing.” (3a) The clay roof, if such was used, may have been laid to a fall either in one incline only like the Cretan attic (Fig. 90), or with a slight ridge or watershed, or all but flat as shown by Chipiez (Fig. 90a).

On the other hand the collecting of rain-water was an urgent need in a country where the water-supply was always a problem. Argos is called by Homer “thirsty Argos,” and the courtyard in front of the palace at Tiryns was cemented and carefully drained into a collecting tank. But flat, earth roofs even furnished

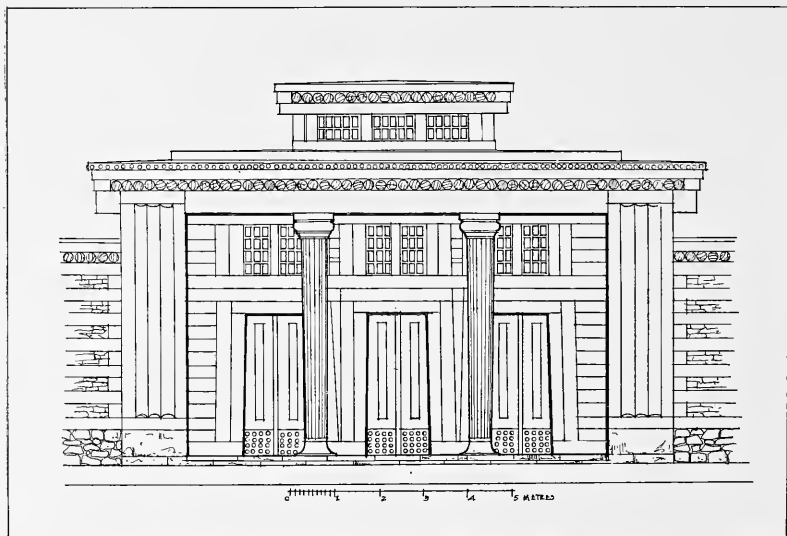


FIG. 90a.—MYCENE. RESTORED PORTICO OF EARLY MEGARON. (*After Chipiez.*)

with gutters are ill designed for collecting rain-water. Also if part of the roof, namely, that over the megaron or hall, was higher than the surrounding parts, as is generally conceded, water overflowing from the upper to the lower would soon destroy an earth covering. The problem which was solved in Mesopotamia by the use of bitumen, in Crete by the use of a cement, and in Egypt scarcely arose owing to the climate, must have been solved by the Mycenaans in a way of their own. It is likely that the vast number of smaller dwellings had flat, earth roofs (Fig. 48) as shown on the well-known silver vase fragment from Mycena

representing a siege, but it is also possible that the palaces had bronze plates or pans and perhaps slabs of stone laid in a clay on the surrounding flats. The use of metal plates as a building material on walls is a commonplace in Homer as we have seen (p. 113). Ægean roofs having ridges were known from early times, as is shown by the thatched hut (Fig. 90b) represented on the stone box from Melos.¹

But evidence of the deliberate shedding of rain as a factor in planning can be seen in the dissociating of the principal hall from its attendant buildings, and its emerging in Hellenic times as an isolated temple with a roof designed to shed water along its flanks.

8. GREEK ROOF CONSTRUCTION

A plan of Troy II., earlier than the Mycenaean palaces, shows four long

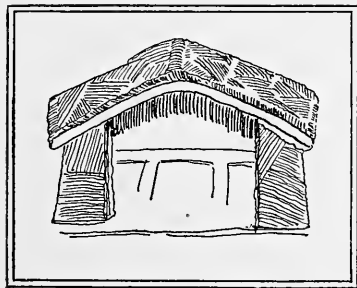


FIG. 90b.—HUT WITH RIDGE ROOF, REPRESENTED ON AN EARLY STONE BOX FROM MELOS (Munich Museum).

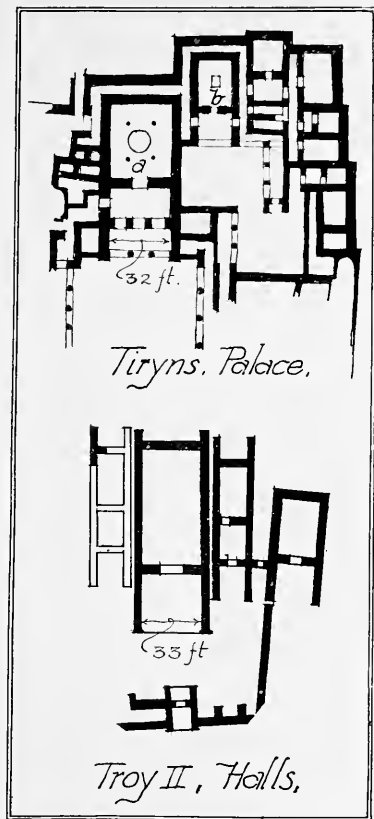


FIG. 91.—PLANS OF ÆGEAN HALLS SHOWING INFLUENCE OF THE ROOF.

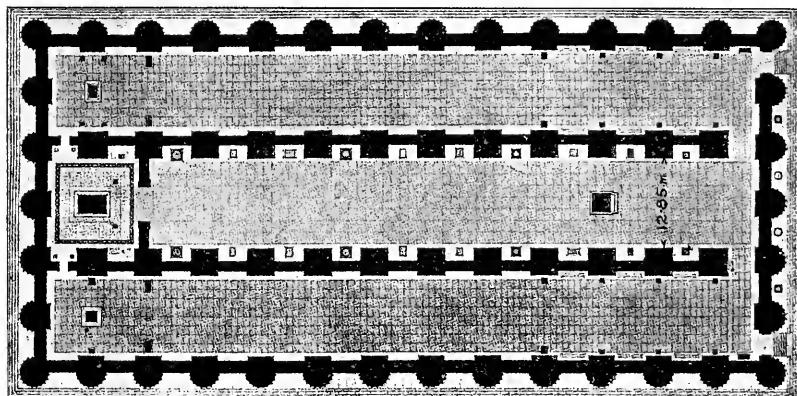
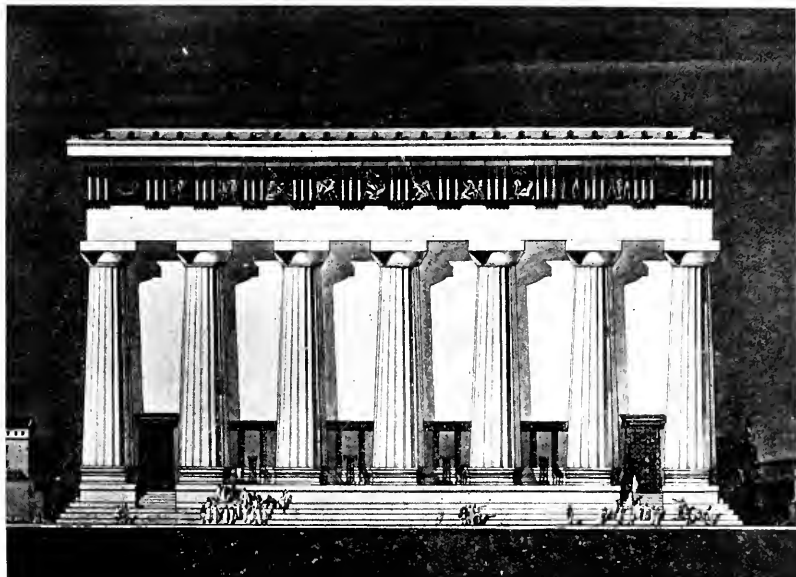
narrow halls set close to each other yet each a separate building (Fig. 91). This

¹ Illustrated in Perrot and Chipiez, *Art in Primitive Greece*, 1894, ii., p. 372.

kind of planning is certainly more primitive than the Cretan or Egyptian, yet with the simplest gable type of roof such as might cover a "basilican farmhouse" (ii. 9 and Fig. 14*a*) or an Ægean hut (Fig. 90*b*) the rain-water problem we have just considered would be easy. The water would fall upon paved areas laid to a fall between the huts or halls. With this is connected the placing of the large entrance at one end which we have also seen to be a characteristic of the "basilican farmhouse." Now this single-cell type of structure in regions where rain is a factor is also probably as old as building itself. It runs right through architectural history and is common to this day. But in the plan of Tiryns¹ (same figure) we can see this single-cell hall joining up with the many-cell or dry climate type such as we have seen in Crete, Egypt, and Assyria: the halls or megaron stand now surrounded by lesser rooms. Also compare the entrance fronts at Troy and Tiryns. At Troy the roof apparently spanned the whole width on the end and left an open room or vestibule having an inner door to the main hall. The same arrangement is suggested in the Ægean hut from Melos (Fig. 90*b*). The thickening of the two wall terminations desirable for the sake of strength led to the Mycenaean and Greek antæ, and led also to the placing of intermediate posts, in other words to columns "in antis." At Tiryns also it can be seen that the northern preference for end doors, and dislike of side doors, still survives. In the Trojan halls there are no side entrances and at Tiryns access from the king's megaron, *a*, (same figure), to the queen's megaron, *b*, is by the most roundabout route through side entrances in the vestibules but not in the inner halls themselves. This is very unlike the excellent intercommunication of the Cretan palaces. It seems then, from the plans, that in the Mycenaean megaron, northern and southern design meet, and an interesting blending occurs, a blending which, in more fields than one, is to have far-reaching effects. The megaron, as we have seen (p. 113), stands surrounded by, but dominating, the lesser buildings on both sides.

But after the Dorian invasion from the north the main hall on the acropolis is found to be again a single building standing dissociated from its neighbours. It is now the temple of the god instead of the megaron of the king (iv. 10), but also it is probable that the loss of Mycenaean building technique and the consequent rain-water problem contributed to separate it. Dorian builders without a knowledge of cement would at first follow northern traditions of structure for northern reasons, and later the sanctity of the building would keep it isolated.

¹ The spans shown in Fig. 91 are approximate only. For scale dimensions in metres see Schliemann's *Tiryns*, 1886, p. 209, and Dörpfeld's *Troja und Ilion*, 1902, p. 81.



[From *Tempio di Giove Olimpico* by Pace and Pierce.

FIG. 92.—RESTORATION OF THE TEMPLE OF ZEUS AT AGRIGENTUM IN SICILY.
(From *Drawings* by S. Rowland Pierce.)

VI. 8. Theory and Elements of Architecture

But however it may have come about, its shape provided the kind of elemental simplicity liked by the Greeks who proceeded to refine it to the highest point. The gable roof with its pediment ¹ became an essential part of the shape. When in Greek Doric an oblong building is given a flat roof or a roof with an attic instead of a gable there should be very good reasons for the change. The flat roof, as we have seen, means historically not a single cell but the agglomeration of cells—the placing of oblongs together. In the temple of Zeus at Agrigento,



FIG. 92a.—WASHINGTON. LINCOLN MEMORIAL. (Bacon.)

as restored by Professor Pace and Mr S. Rowland Pierce,² the plan shows not a single hall but three long halls side by side surrounded by a huge wall, having engaged Doric columns, and logically enough, the end gable or pediment has been omitted (Fig. 92). In the modern Lincoln Memorial at Washington the building is to be read from the long side, consequently the flank is to become the front, and the parallel with the orthodox Greek temple is lost. Hence the absence of the pediment and the presence of the attic (Fig. 92a).

¹ The Greek for pediment is *actos* or “eagle.” Various passages in Greek literature suggest that the Corinthians, who are said to have invented ceramic roofing tiles, also invented the “eagle” or pediment. (See Aristophanes, *Birds*, 1110; Pindar, *Olympian*, xiii. 21; also Bury's *History of Greece*, 1900, p. 152.)

² Pace, B., and Pierce, S. R., *Tempio di Giove Olimpico in Agrigento, Monumenti Antichi*, vol. xxviii., Roma, 1922. In this restoration it can be seen that the centre part of the building corresponds to the cella and naos of a Greek temple, the side halls or aisles being places of assembly.

The Greeks took the shape of this gabled oblong and made of it æsthetically something unsurpassed in history, but from the point of view of construction they left it quite undeveloped. The roof was given a pitch of about 15 degrees, and the tiles and the gutters were developed as we shall see (vii. 1) to the highest water-proofing efficiency. But beneath the marble tiles the carpentry is really as elementary as the primeval bearer roof we have been discussing. This can best be illustrated by quoting the roof clauses from Philo's specification for the arsenal of the Piræus (4), which owing to Choisy's researches can be clearly followed. The arsenal differs constructionally from the ordinary Greek temple only in having its piers inside and cella wall outside; but the result of this is that the

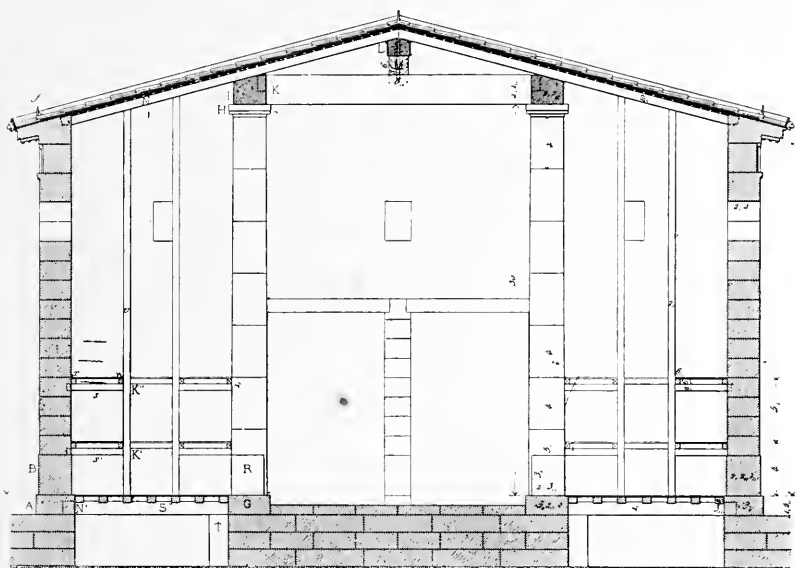


FIG. 93.—SECTION OF THE ARSENAL OF THE PIRÆUS AT ATHENS ILLUSTRATING THE ROOF CLAUSES OF PHILO'S SPECIFICATION. (From Choisy's *Etudes Epigraphiques*.)

lintels which are of wood and the roof timbers above can be the more clearly compared with primitive origins. The roof clauses begin at line 45. They can be best followed with reference to the section, Fig. 93.

VI. 8. Theory and Elements of Architecture

“And he will place upon the piers (*kionas*) wooden lintels *I* (*epistylia*), fastened¹ together, five half-feet in width, height nine palms on the higher of the two faces, number eighteen on each row. [Each lintel therefore spanned two incolumniations.]

“And he will place upon the piers above the passageway cross beams *K* (*mesomnas*) corresponding in width and height to the lintels.

“And he will place [above the cross beams] ridge pieces *L* (*koryphaia*)² seven palms wide, five palms and two fingers in height, not counting the chamfer (*kataphōras*), after placing a support *M* (*hypothēma*) three feet long and three half-feet wide upon the cross beam.

“And he will fix at intervals the ridge pieces to the cross beams by means of pins (*kerkisi*): and he will place [on the ridge pieces] rafters *N* (*sphēkiskous*) ten fingers thick, three palms and three fingers in depth and placed at five palm intervals. And having set on [the rafters] battens (*himantas*) one half-foot wide and two fingers thick at intervals of four fingers, and on these set [wood] sheathing (*kalymmata*) six fingers by one nailed with iron nails, [then] coating it, he will tile with Corinthian tiles fitting closely one with another.”³

“Nothing,” says Choisy, “is simpler than this construction, but nothing differs more profoundly from our practice. With us the cross beam is essentially a member under tension—a tie. Here the cross beam is a bearer. The idea of a *truss*, that is to say a combination of members in which the weight of the roof is translated into a tensile stress (or pull in a tie-beam), this idea fundamental to carpentry is here entirely absent. The whole roof is only an assemblage of pieces of timber leaning one upon another, the loads of which act vertically downwards and are not converted into tension at any point. Considering everything it marks a very primitive phase in the art of carpentry.” (4)

In the clauses of the specification we have quoted above, the term to *place* suggesting masonry is used throughout, and the expression *fitting together*, suggesting carpentry, is used only once.

The lintels and cross beams were of enormous size and formed a great platform resting upon the piers. Upon this platform, or “flat” the rafters are rested at an inclination caused by slightly raising them at the centre of the building and letting their feet rest against the cornice stones of the walls. The ridge piece (Greek *koryphia*, Latin *columen*) was intended to carry weight, and the

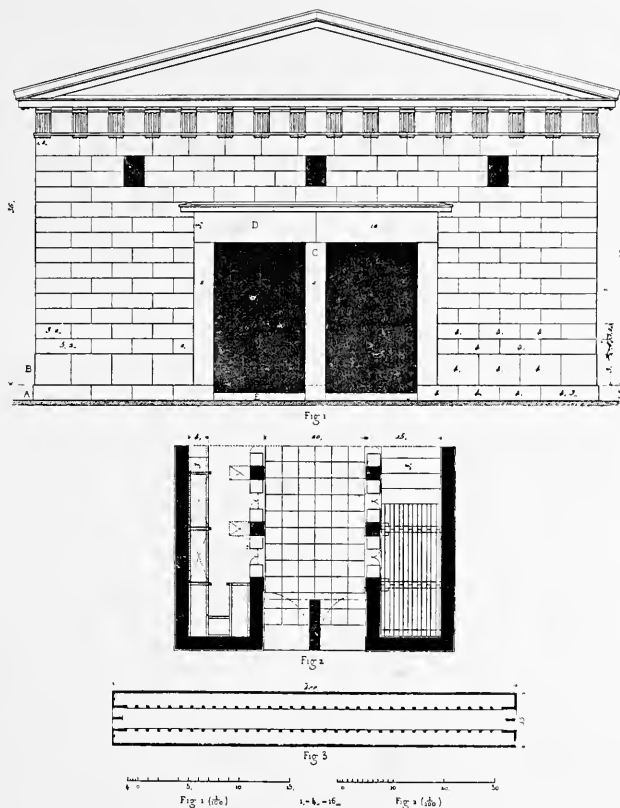
¹ Literally, “as if glued together.”

² Called *Columen* by Vitruvius. Book IV., ch. ii. (See also Fig. 95.)

³ Translation from the Greek text of Choisy, by Mr G. E. Meister.

inclination of the rafters was not sufficient to cause any considerable thrust against the walls.

In addition to the primitive carpentry a glance at the arsenal plan (Fig. 94)



[From Choisy's *Etudes Epigraphiques*.

FIG. 94.—ATHENS. ARSENAL OF THE PIRAEUS. ELEVATION AND PLANS.

shows us how close we are still to the early oblong cell structure. The building is of enormous length ; owing to the primitive roofing it was more economical for

an increased accommodation to cause an increase in length rather than width. The builders were in fact dependent upon the strength of cedar, cypress, or poplar under simple bending stress; spans beyond a certain size could not be roofed, and therefore floor space was restricted. And in fact we actually find it recorded by Strabo¹ that the Greek temple at Miletus "exceeded in size all others, but it remained without a roof on account of its magnitude."²

9. ROMAN AND EARLY-CHRISTIAN ROOF CONSTRUCTION

The Roman builders with their instincts for fine construction by no means confined themselves to the bearer type of roof characteristic of the Greek. We do

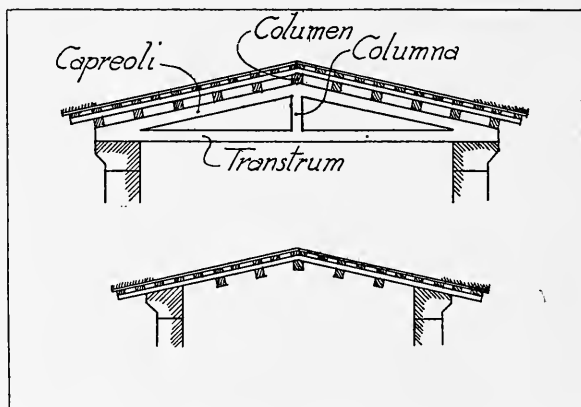


FIG. 95.—ROMAN ROOF CONSTRUCTION ACCORDING TO VITRUVIUS. (After Choisy.)

not hear of any Roman building that had to remain un-roofed because of its wide span. Vitruvius recommends two roofs (Fig. 95), one for small, one for large spans. In the smaller the purlins span from wall to wall and are really loaded beams; the principle of construction is precisely the same as that of the Piraeus arsenal

¹ Strabo, *Geography*, translated by Hamilton and Falconer, Book XIV., vol. iii., 1, 4. Bohn, 1857, Casaub. 634.

² Mr S. Rowland Pierce suggests that it was for the same reason that the temple of Zeus at Agrigentum, already referred to, remained without a roof and incomplete at the time of the sack of Agrigentum by the Carthaginians some seventy-five years after its foundation.

(Fig. 93). But "if the roof be of large span, a ridge-piece (*columen*) is laid on the top of the post (*columna*), . . . and a tie-beam (*transtrum*), and struts (*capreoli*) will be necessary." (5)

This mention of a transtrum or tie-beam is of vital importance in the history of structure. It means the beginning of modern carpentry, and the development of that class of roof shown in column *III.* of Fig. 77, to which modern steel trusses belong (vi. 3). In Vitruvius' larger roof the "*columen*" or ridge-piece is not really a beam supporting the roof at its centre as in the earlier roofs but carries no load at all. The "*capreoli*," or rafters are not in bending stress but in compression, and transmit the load which is in turn resolved into a pull on the transtrum or tie-beam and a vertical load on the walls. Without a true carpentry the large spans of the Roman unvaulted basilicas,

such as the basilica Julia, the basilica of Trajan, and Constantine's nave of St Peter's spanning nearly 80 feet, could not possibly have been covered by timber construction alone. In the case of the great vaulted halls of the Baths, where outer timber roofs existed, the timbers probably rested on the extrados of the vault.

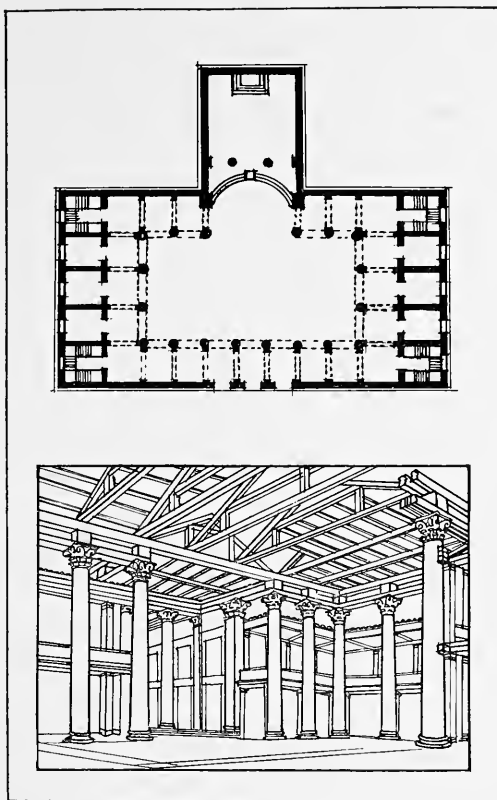


FIG. 95a.—BASILICA OF VITRUVIUS AT FANO.
(After H. L. Warren.)

vi. 9. Theory and Elements of Architecture

But the timber-roofed Roman basilica, or Hall of Justice, had an important part to play in the history of structure. It survived the vaulted basilica in Rome

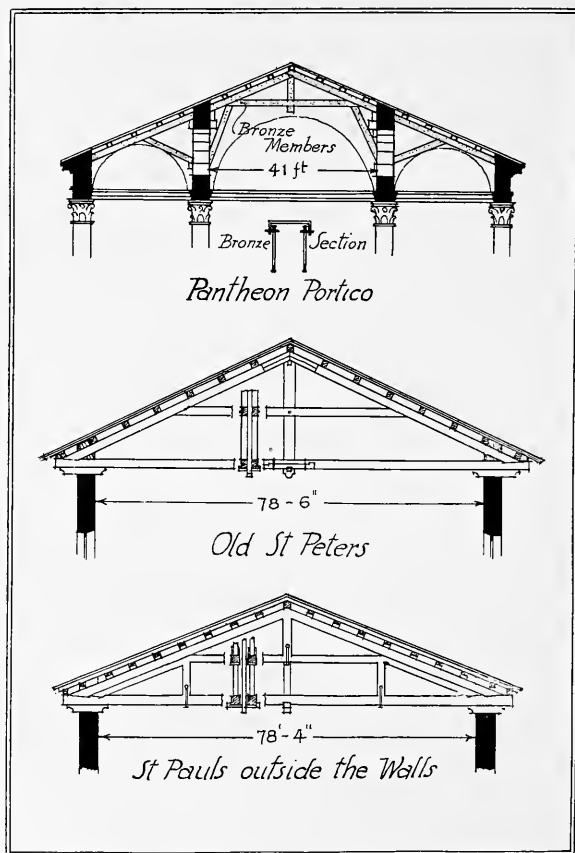


FIG. 95b.—ROMAN BRONZE TRUSS AND EARLY-CHRISTIAN TIMBER TRUSSES.

and became the roof type for the early Christian assembly church. "At the time of Constantine the vaulted construction in brick which had been one of the

glories of imperial Rome came to an end. The old capital abandoned vaulting, and down to the end of the first millenium produced no other kind of church than the wooden-roofed basilica."¹

Vitruvius himself built a wooden-roofed basilica in the time of Augustus, at Fano, which he has described (Book V. Chap. I.) having galleries as a kind of promenade. The Roman basilica was a building of great importance in Roman city life. It adjoined the forum and was used not only as a Hall of Justice but also as Market and Exchange. As such the aisles with the galleries over them were of considerable use. An illustration is given of Vitruvius' design (Fig. 95*a*) after Mr Warren's reconstruction, in Morgan and Warren's edition of Vitruvius. Its span between the nave columns was 60 Roman feet, something less than the same dimension in English feet. Vitruvius especially mentions the "agreeable effect" of the view of the roof both outside and inside, and at the same time mentions the cheapness and simplicity of the design. There is no mention of roof thrust or of problems arising from roof thrust, which suggests that the "transtra" did their proper work. They are seen in the figure. In the roofs of the Basilica Ulpia and of the Pantheon portico (6) bronze members were used (Fig. 95*b*). This of itself suggests the recognition of tensile stress although doubtless they were also used for resisting fire.

It is probable that in the wood roofs of the early Christian basilicas as surviving in Renaissance times we see also Roman timber construction of the later empire. The trusses of old St Peter's, and of St Paul's outside the walls² before its destruction in the nineteenth century—both churches founded by Constantine—are given in the same figure. In

both roofs the "king-post" is recognised to be in tension owing to its pinning beneath the tie-beam. It is treated as a strap, as can be seen in the section of



FIG. 95*c*.—ROME. WEST FRONT OF ST LORENZO.

¹ Dalton, O. M., *East Christian Art*, 1925, p. 71.

² Kraft, J. Ch., *L'Art de Batir*, 1805, Pl. xi. For the roof of St Peter's see Letarouilly's *Le Vatican*, 1882, vol. i., pl. 5.

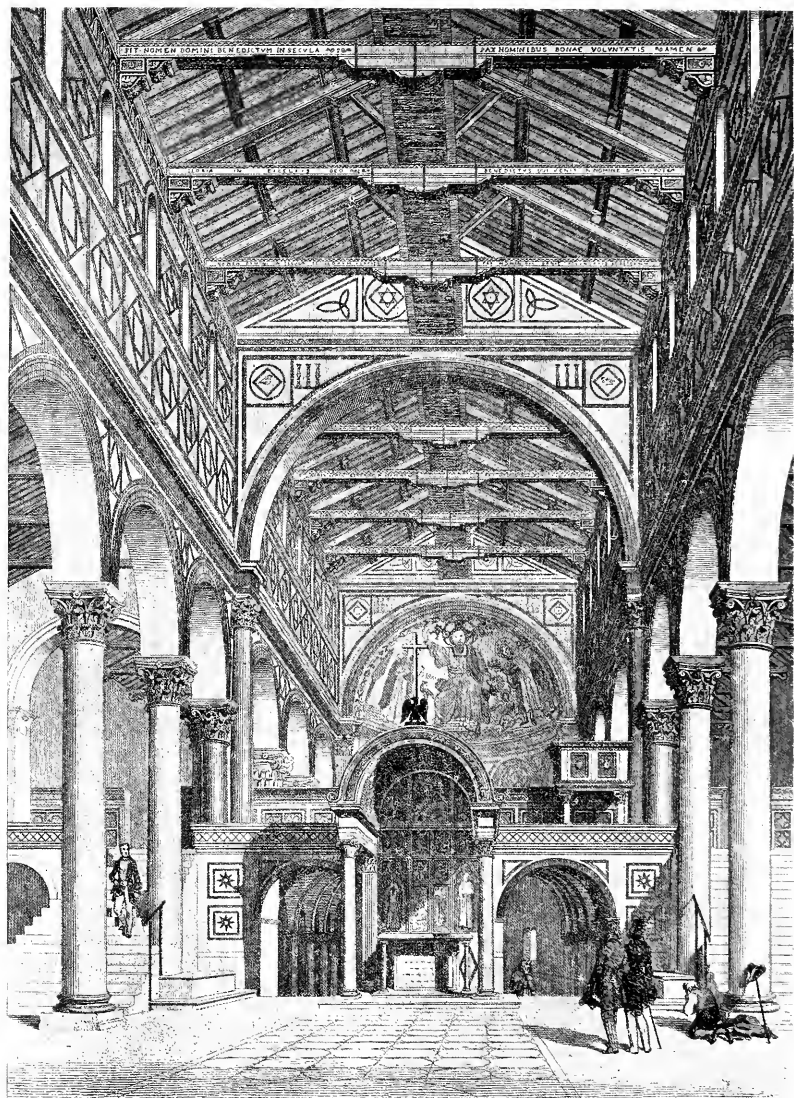


FIG. 95.—FLORENCE. ROOF OVER ST MINIATO. (From Gailhabaud.)

St Peter's the principal rafters and tie-beams are doubled in each truss and the pairs of tie-beams grip the king-post between them. In the St Paul's roof the queen-posts are doubled with the other members and the king-post hangs free, except at the bottom where it is pinned to the tie-beams. These trusses covered spans greater than Gothic vaults and endured for centuries. Also the tie-beams and their sole pieces projected externally and formed a cornice along the flanks



FIG. 97.—ROME. INTERIOR OF ST PRASSEDE.

of the building. When the basilica roof is hipped at the west end and these projections are returned and masked by plaster, then a characteristic basilican front is produced as at St Lorenzo in Rome (Fig. 95c) or the old fronts of St Peter's and of St Paul's.¹ Internally the open timber roofs were often carved and painted in reds, whites, and blacks. A beautiful example is the church of St Miniato near Florence (Fig. 96) in which the horizontal tie-beams contrast with the transverse wall arches.

There had always existed in Italy an old Roman tradition of dividing up a timber roof into bays by means of transverse wall arches. This can be studied

¹ This is well seen in Piranesi's etching of St Paul's outside the walls, made before the fire.

VI. 10. Theory and Elements of Architecture

also in the early Christian churches of St Prassede in Rome (Fig. 97). The wall in the Roman basilica was even carried up outside and formed a kind of party wall between one bay and another. (8) By this means a certain measure of fire-prevention was secured, since a fire in the timbers in one bay might less readily spread to another. By this means also the purlins might span from gable to gable and help to support the roof. But in whatever way they originated it is certain that the transverse arches of the early Christian basilica were useful, and we can follow their action at St Ambrogio in Milan where they form natural abutments for a series of vaults and thus initiate the medieval method of vaulting by compartments.

We have seen already how early Christian churches made use of pagan columns (p. 62), "converting" them often by placing a pulvino or impost block over the Classic caps. We must now add the facts of the large spans, the fine Roman carpentry, the similarity in plan and structure to the Roman timber-roofed halls. The early basilican church was indeed not only church, but also bishop's court and hospital as well. The Christian building had great strength and simplicity; it had great adaptability, and also the capacity—as we shall see—to absorb whatever structural systems it required.

10. MEDIEVAL ROOF CONSTRUCTION

If the roof used to cover the basilica of St Paul's, outside the walls of Rome (Fig. 95*b*), was indeed originally a true truss having tie-beam and post designed to be in tension, as was likely (vi. 9), this advanced carpentry seems not to have reached the northern Romanesque builders of the succeeding age. In both England and France the Romanesque "tie-beam" was of great thickness and designed to carry weight and support the roof at its centre rather than tie in the feet of the principal rafters. In other words it was of the bearer type (Fig. 77). In England this bearer tradition persisted for centuries as we shall see. But though the "width of the great Norman churches was conditioned only by the length of the tie-beams by which they were spanned"¹ yet the spans were often considerable. The beams spanning the Norman nave of Winchester were 45 feet long; at a later date many Gothic cathedrals were content to reproduce the original Norman spans. But huge timbers had to be employed—the sizes of the Winchester tie-beams were 12 × 20 inches—and the flat wooden ceilings characteristic of many Anglo-Norman naves were probably in essence the soffits of bearer

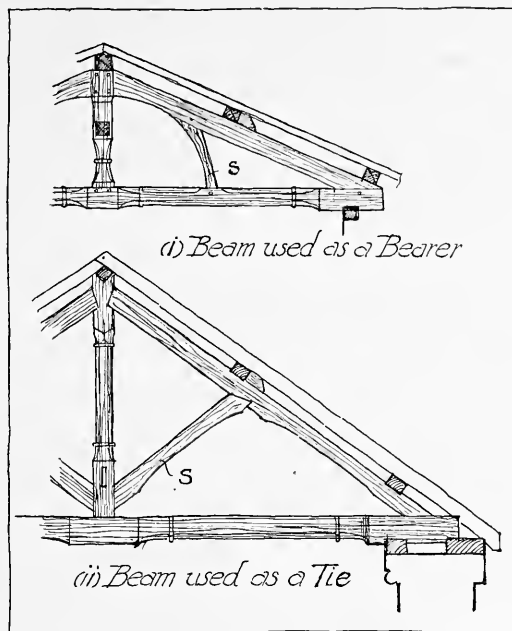
¹ Bond's *Gothic Architecture in England*, p. 15; the term "tie-beam" is misleading.

roofs. The great thickness of Romanesque clerestory walls formed part of this early roof system. But both in England and France supplies of heavy slow-grown timber became exhausted and clerestory walls became narrower; and developments occurred. The developments were different in the two countries.

We will first follow the French. In France, Viollet-le-Duc early traces the recognition by designers of the tie-beam as a member in tension and as ill suited to carry loads. The angle of the strut supporting the purlin at the centre of the principal rafter, which in the earliest type was as shown in Fig 97*a* (i), was soon changed to that shown in (ii), that is to say to a true king-post truss. The shifting of that strut from bearing upon the beam¹ to bearing upon the king-post is a radical change. It is likely that this recognition occurred

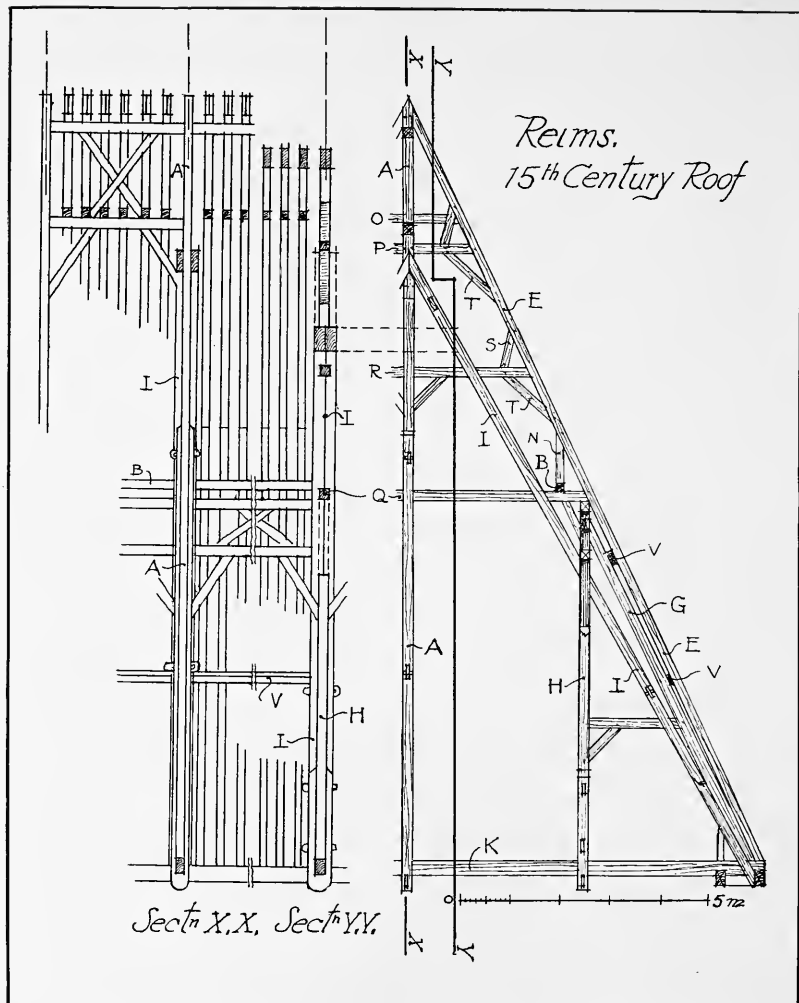
early in France, in view of the brilliant French timber engineering that followed in the Gothic period. The French method of timber growing also contributed to the roof development. It has already been pointed out that the difference between the growth of the English and French oak (ii. 9)—the same in species—helped to produce a difference in the timber construction of the two countries. The French oaks, planted close together, grew tall and straight (Fig. 14), and long

¹ Examples of this early type, according to Viollet-le-Duc, were to be seen at Lagorce near Blaye, and at Villeneuve. (7)



[From Viollet-le-Duc.]

FIG. 97*a*.—EARLY FRENCH ROOFS.



[From Viollet-le-Duc.

FIG. 98.—REIMS. GOTHIC TRUSS WITH TENSION MEMBERS FULLY RECOGNISED.

straight timbers were supplied to the French carpenters. With these they built a very light truss covering large spans and capable of acting as a tie to the structure above the vault. A truss of this type, namely that over Reims Cathedral¹ before the war of 1914, is illustrated from Viollet-le-Duc (Fig. 98). Unlike the English carpentry it consists of very light timbers scarcely more than 10½ inches in section at any point.² The vertical posts A, and H, are often double timbers and below a certain point can be seen to act as straps supporting the tie-beam. In the case of the roof of St Ouen at Rouen the shorter posts are frankly treated as straps (Fig. 99), and are so cut away that if they came under compression they must snap. (7)

The full recognition by the French builders of the tie-beam as a member in tension only, and not as a bearer designed to support the roof at its centre is an important item in Gothic design. A bearer beam heavily loaded tends to bend downwards and the ends to pull away from the wall. This would have been dangerous in conjunction with very thin clerestory walls and thrusting vaults. The advantage of a truss—that is of a roof frame which neither pulled nor pushed—was obvious. It is probable that when a new church was built in the thirteenth century the roof built first upon the clerestory walls

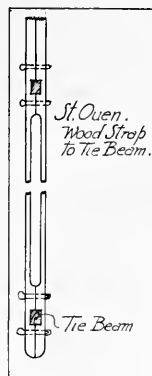


FIG. 99.—ROUEN. ST OUEN. VERTICAL WOODEN TIE.

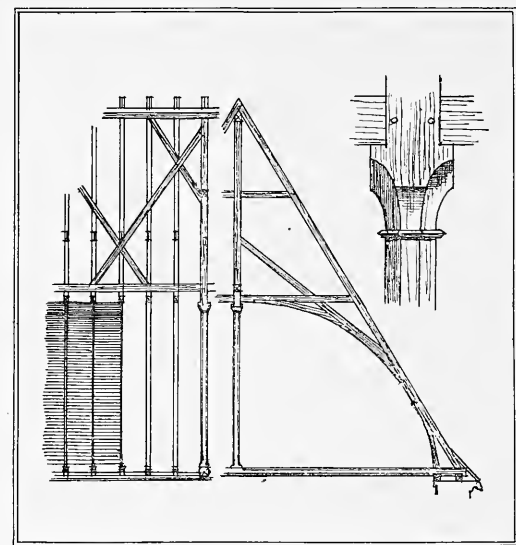
¹ Trusses of this type also survived as late as the nineteenth century at Paris and Rouen, and were examined by Viollet-le-Duc and by Choisy.

² The following is a rough analysis of the stresses in this truss (Fig. 98). Principal rafters, E, are stiffened against bending under load in their upper half by a series of horizontal braces, P, R, Q, and angle-pieces, S, T, and in their lower half by an additional member, G, which increases the effective depth. These principals, strengthened thus against dead load, are prevented from spreading by a long tie-beam, K, spanning from wall plate to wall plate; this tie-beam is supported at three points by being strapped up to the ends of a series of vertical posts, A, H, which play a complex part in the structure. Resistance to distortion by wind pressure is provided by coupled braces, I, resembling principals in appearance, running from wall plate to centre post. One or more of these extra couples is provided in each principal truss; they are double timbers and grip all the members they cross, so that their stiffening value is considerable. Intermediate rafters are in the same plane as the principal rafters, and are strengthened by struts, N, carried upon a bearer, B, and by the purlins, V; they are stiffened near the top by braces, O. The horizontal braces, P, R, Q and O, are not "collars" in the modern sense, that is to say their function is not to help tie in the principals and prevent spreading; on the contrary they are in compression, and in conjunction with the angle-pieces, S, T, probably act as a kind of web.

It is difficult in roofs of this kind where the members support each other, to apportion the stresses correctly, owing to cross strains. In the truss under consideration the principals, E, and the horizontal

was also used to protect the vault from the weather while in process of construction. (8)

In secular buildings the French recognition of the tie-beam as a member in tension is seen in their wooden barrel roofs (Fig. 100) in which the tie-beam



[From Viollet-le-Duc.]

FIG. 100.—AUXERRE. FRENCH WOOD BARREL CEILING WITH TIE-BEAM SHOWING.

and hanging-post are frankly shown. This type of roof came about owing to the desire to get extra head-room by using the space above the level of the wall-plate in the design of an interior. The wooden barrel or waggon ceiling in France was no doubt partly the imitation of vault building (7), but the tie-beam and its supporting post were recognised and included within the barrel as necessary parts. Their tensile stress is recognised in their thin section and chamfered edges.

The English solution of the same problems was very different. The extra height above the wall-plate was obtained by a system of roof-building that evolved the “hammer-beam.” The English oak, unlike the French, remained large limbed and curved, and English carpenters used the branch where the French used the stem (p. 39). The sizes of English timbers remained large. From the earliest times English carpenters had striven for an extra head-room and had either failed to

braces, P, R, are in compression, the tie-beam, K, is in tension, and the centre post, A, is in tension from about the centre point where it is jointed, downwards. The side posts, H, are probably under cross strain above the horizontal brace, and are in tension below. The coupled braces, I, are in tension or compression according to the direction of the wind.

recognise or deliberately rejected the principle of the tie-beam. In England, medieval tie-beam roofs are crude structures compared to the French. Where they occur the tie-beam is heavy and frequently slightly cambered. (9) The English builders placed a post upon it in order to support the apex of the roof—that is to say they wished to treat it as a bearer and to treat the post as in compression. At Swardestone, Norfolk (Fig. 101), and at Woodnesborough in Kent (Fig. 101*a*) the post has above it a series of brackets supporting both ridge and principals.¹ Also from the earliest times in England there had existed

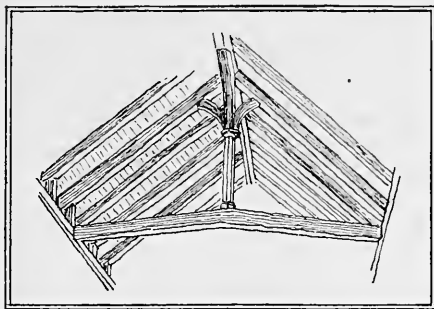


FIG. 101.—ENGLISH BEARER-BEAM ROOF, SWARDESTONE CHURCH, NORFOLK. (After Brandon.)



FIG. 101*a*.—WOODNESBOROUGH CHURCH, NEAR SANDWICH, KENT.

[H. B.]

the parallel tradition of the wooden cruck (2) or arch brace. This member partly supported the roof ridge and at the same time distributed thrust far down the wall surface or else carried it right to the ground as at Luntley Court (Fig. 102). This type of roof was sometimes used in combination with the tie-beam as in the nave of Morton Church, Lincs. (same figure) and St Mary, Pulham, Norfolk. The result of this combination of traditions was a type of roof such as that of North Walsham (Fig. 103) in which the tie-beam acts partly as a bearer, supported from below by bracket-pieces and supporting other bracket-pieces above, and partly as a stiffener and

¹ Other examples of the bearer roof of this type are: Woodbastwick Church; also St Mary's Westerham, Headcorn, Tenterden, and many others in Kent.

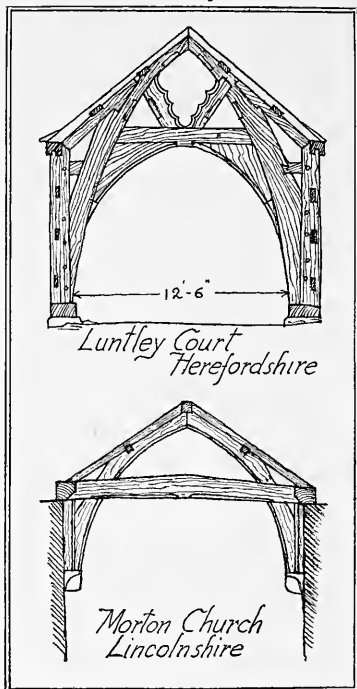


FIG. 102.—ENGLISH CRUCK TRADITION COMBINING WITH THE BEARER TRADITION.
(After Innocent.)

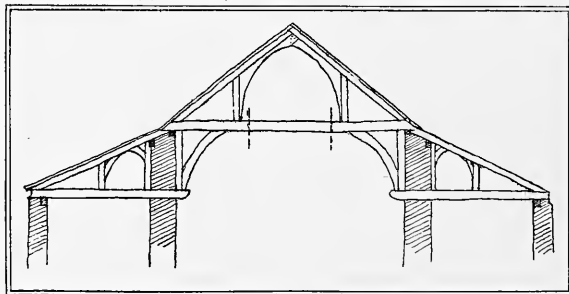


FIG. 103.—NORTH WALSHAM. NAVE AND AISLES.

tie. It had little value, if any, as a tie in cases where the roof was well buttressed by one means or another—as in the case of North Walsham. The centre third of the tie-beam over the nave at North Walsham might have been cut away without danger of spreading (*see* Fig. 103). The result would then have been a hammer-beam roof. The principle of the hammer-beam roof is the building up of a series of brackets able to carry the load, and at the same time distribute the thrust down the wall below the plate. Equilibrium depends largely upon the rigidity of joints, and English carpenters were highly skilled in jointing heavy timbers. (2) Here the English roof again differs from the French roof we have just considered (Fig. 98), which in skeleton is a true truss and might, theoretically, have been pin-jointed. But the hammer-beam roof in spite of the best rigid jointing exerts some thrust against the walls, and the members below the wall-plate are as important as those above. In spite of precautions the walls have often to be

buttressed afterwards or tied in. The fine hammer-beam roof over the nave of March Church has had to be tied in with steel ties at the level of the wall-plate, thus spoiling the rationale of the design. The

roof over Westminster Hall, built for Richard II., required buttresses extending 30 feet beyond the walls (Fig. 104).

Westminster Hall roof, as built for Richard II. by Hugh Herland at the close of the fourteenth century, is more than a hammer-beam roof; it embodies in fact the hammer-beam method, the tie-beam method, and the ancient cruck or arch brace method. It sums up the English medieval genius for construction, and reveals both the confusion of principles and the mastery of practice characteristic of the race. We have seen that the original Norman roof at Westminster Hall was probably carried upon beams resting upon timber piers (Fig. 14*b*), and if this was the case the intention in design was that of supporting the roof at its apex and intermediately. It was therefore of the bearer type; thrust was not intended to be exerted against the walls nor yet was there a true tie-beam holding in the feet of the rafters.¹ When Herland had to span the same width without intermediate columns, he could find no timbers long enough either to reach from wall to wall as bearers, or to form principal rafters in one piece. He had, therefore, to build up a framed truss out of timber lengths. He designed this truss as it were in three steps. First, starting some 21 feet below the wall-

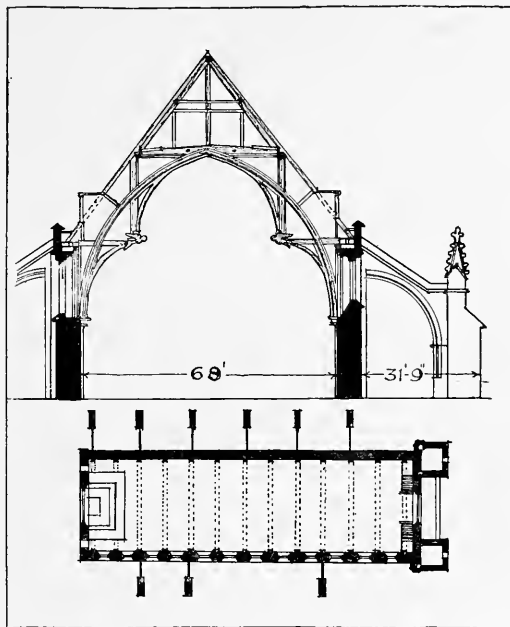


FIG. 104.—SKETCH SECTION AND PLAN OF WESTMINSTER HALL, SECOND ROOF, SHOWING BUTTRESSES.

¹ It is interesting to compare and contrast the Norman Westminster Hall roof (Fig. 14*c*) with that of North Walsham, including the aisles (Fig. 103).

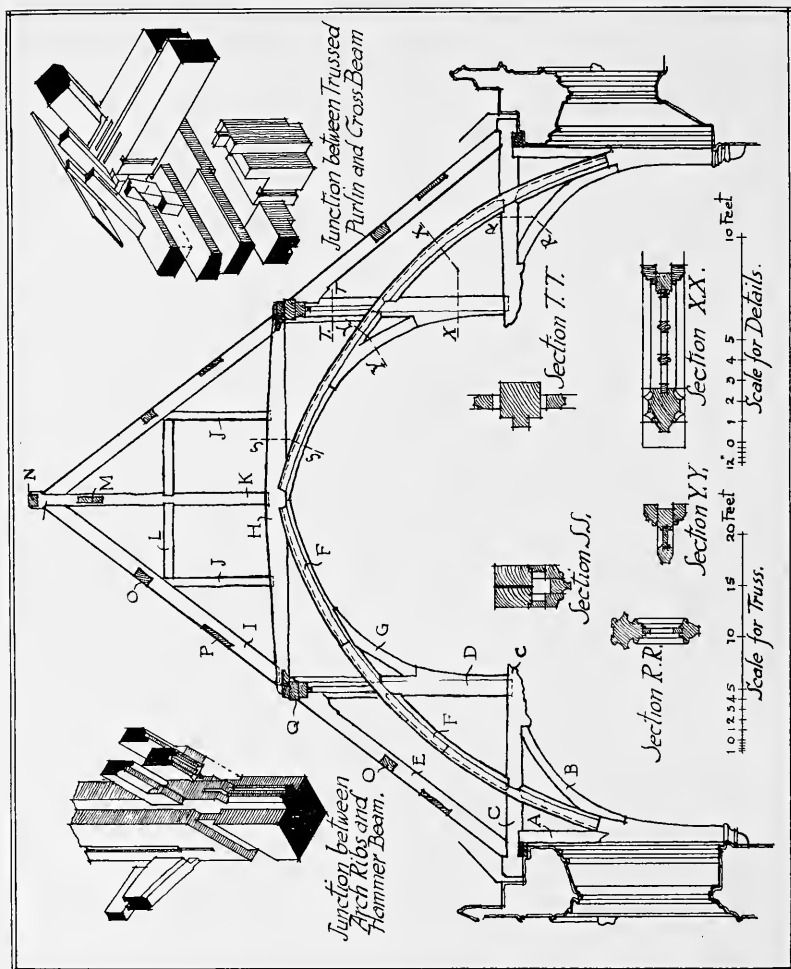


FIG. 104a.—WESTMINSTER HALL. MEMBERS OF THE ARCH AND HAMMER-BEAM ROOF.
(After Report by Sir Frank Baines, H.M. Office of Works.)

plate (Fig. 104a) he built out two cantilever structures on the hammer-beam principle, out of hammer-beam C, hammer-post D, wall-post A, and the lower principal rafter E. The feet of these lower principals, E, with their load acting vertically downwards pin down the ends towards the wall of the hammer-beams, C, which at their other ends are strutted up and kept horizontal by means of bracket pieces, B. These two cantilever structures carry first the trussed purlins, Q. These trussed purlins consist each of three timbers and have to bridge 19 feet between the principals. Over them and resting upon them is the upper portion of the roof truss.

This upper portion consists of a frame in which the cross beam, H, takes the feet of the upper principal rafters, I, which are also stiffened by struts L and J. At the same time by means of crown-post, K, and branching-struts, M, the cross-beam, H, acting as a bearer supports a ridge-piece, N.

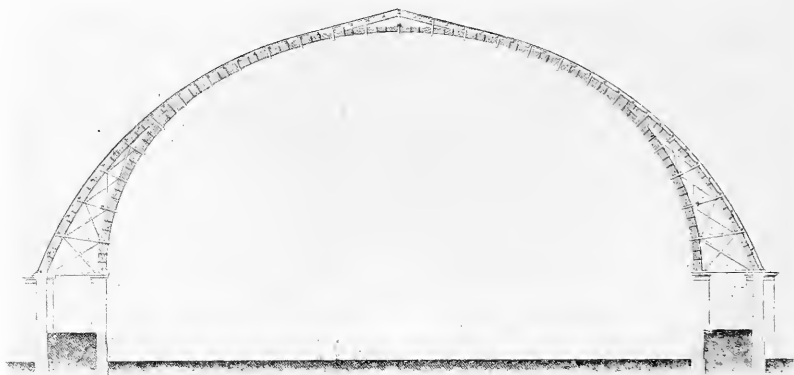
The third step in the design was to introduce two huge crucks or arch braces, F, serving a double purpose: they both stiffen the lower or cantilever members and at the same time help to support the upper framed structure at its centre point. These crucks, primitive in their origin, and serving the primitive purpose of supporting the roof at its centre are the real feature of the Westminster roof. The structure began to fail by the decay of joints upon which, as we have seen, the hammer-beam roof largely depends. Also the purlins, O, spanning some 19 feet between trusses were too small in section for their load. But for centuries Westminster Hall has stood a monument to the empiric English craftsman, actually covering a wider unimpeded space than any English stone vault or, with a few exceptions, than any vault in the world. Westminster is wider, for instance, than Albi nave spanning 60 feet, and exceeds the span of Cologne vault by some 24 feet. To surpass it we have to refer to the 70 and 80 feet spans of the Roman concrete vaults and the true trusses over early Christian basilicas. One effect, however, of the huge timbers is that the interior does not look its size. The walls are now bare and there is little to give the scale. But this unemphasised grandeur has its own value and, as a setting for national functions, when myriads of human figures are present and give a unit of measurement, the building is unsurpassed.¹

¹ The length of the hall is 240 feet, the width originally 69 feet. The height to the ridge piece above the original floor is over 90 feet. The building is divided into twelve bays, about 19 feet 6 inches centre to centre, with two smaller end bays. The roof is of oak throughout, obtained from the king's wood of Pettelewode in Sussex, from the king's park at Odiham, from the wood of the abbot of St Alban's at Burnham, and from a wood near Kingston-on-Thames. The oak as originally worked was not seasoned but allowed to season *in situ*. Oak pegs were used at first in all joints. The arch brace is of

VI. II. Theory and Elements of Architecture

II. ROOFS OF LARGE SPAN

The span of the large king-post roof truss over Covent Garden Opera House is 82 feet at 13 feet 2 inch centres¹—about 3 feet wider than the trusses over old St Peter's. This is the limit of ordinary timber trusses but the requirements of the early industrial age led to some ingenious timber engineering. At the close of the eighteenth century, market-places, exchanges, and riding-schools were



[From *Nouveau Système d'Arcs*.

FIG. 104b.—A FRENCH TIMBER TRUSS FOR WIDE SPANS PROJECTED BY COLONEL EMY IN 1828.

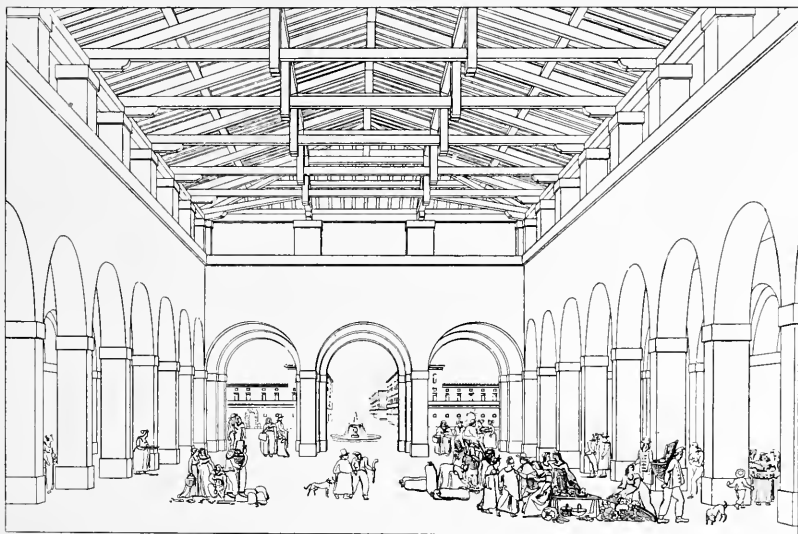
designed having timber trusses of an elaborate kind. Some of these can be studied in Krafft's *L'Art de la Charpente*, published in 1805. In 1828 was published a French text-book on a new system of trusses for carpentry of large span by A. R. Emy (Colonel du Génie en retraite), entitled *Nouveau Système d'Arcs*, in which wooden trusses are built up in sections on a principle originally advocated by Philibert de L'Orme, a French architect of the sixteenth century. Cavalry barracks of the size of Olympia spanned by timber roofs were projected by Colonel

three members, each 9×12 inches, the "collar" beam consists of two members, each 19×12 inches, and 40 feet long. The principal rafters are out of 17×12 inches. The hammer beam is out of $22\frac{1}{2} \times 21$ inches, and 18 feet long. (See sections in Fig. 104a.) Oaks having diameters of 4 feet to 5 feet, with limbs from 25 feet to 40 feet at this diameter, must have been used. The stone used was Caen stone and "Reigate ashlar." Lead for the roof was had from the High Peak in the County of Derby. (*Blue Book, Westminster Hall*, Report by Sir F. Baines, H.M. Office of Works).

¹ Ellis, *Practical Carpentry*, 1906, p. 83.

Emy (Fig. 104*b*), and a riding school, illustrated in Tredgold,¹ spanning 235 feet is said to have been built at Moscow on the Emy system. This movement, however, was brought to an end by the introduction of iron members for tension.

The treatment of buildings of large span in the early nineteenth century was often excellent. The markets of Paris, as for instance the *Marché de St*



[From *Foires et Marchés* by Bruyère.

FIG. 104*c*.—PARIS. OLD MARKET OF ST GERMAIN.

Germain (Fig. 104*c*), seemed to carry on the Roman basilican tradition of Vitruvius or the basilica Ulpia—a tradition that remained entirely logical. In the *Marché St Germain* the timber trusses rest on points of support resembling those in Vitruvius' basilica at Fano (Fig. 95*a*). The whole design is neat and strong.

Masonry and timber were sometimes combined for large buildings in the form of wide span arches carrying timber purlins. This also embodies the early tradition (vi. 9) of transverse arches and purlins as at St Miniato (Fig. 96). A

¹ Tredgold, T., *Elementary Principles of Carpentry*, 1886, plate xxi.

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roof of this kind is shown in the old Octroi General in Paris (Fig. 104*d*). To-day this type of roof could be developed in reinforced concrete.

Iron members would probably have been used in roofs even earlier than they appear to have been were it not for the difficulty of making a satisfactory joint between the oak and the iron. Oak tends to destroy iron, and the oldest oak roofs in the country are pegged with wooden pegs and have not a nail in them.



FIG. 104*d*.—PARIS. THE OLD OCTROI GENERAL.

[From Pugin and Heath.]

But timber was always liable to shear at the ends and fastenings of members in tension; hence the pegs and shoulderings of king-posts and the long projections of the butts of tie-beams in ancient trusses (Fig. 95*b* and 104*c*). Iron, therefore, was used first, quite logically as straps or stirrups for jointing timber members, also as ties through old wood floors that required strengthening, and finally for roof members in tension. The tie-beam and king-post or king-bolt could be in iron, and principal rafters in timber (Fig. 104*e*). Timber has always held its own as a roofing material, and is likely to continue to do so for small spans, because

it is homogeneous, and suitable both for compression and tension (p. 97); but from the simple selecting of materials for stresses as in Fig. 104e there developed quite logically, in the nineteenth century, the reinforced concrete systems. Concrete could be moulded into sizes suitable for floor or roof members, it is excellent in compression, and steel rods inserted in it in suitable positions—if they could be made to adhere to the concrete—would take up the tension.¹ A reinforced concrete truss therefore—if steel and concrete adhered—had the properties of a stronger timber truss, and wider spans could be covered. But the iron requires

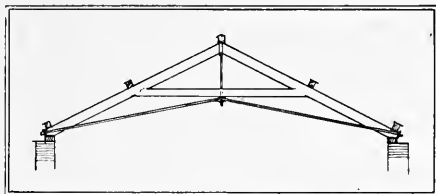


FIG. 104e.

to be protected from the air in order that it shall not rust and expand, and crack the concrete; part of the concrete must then act as a skin or protector to the iron. These facts should be recognised by designers. A reinforced concrete lintel or roof member is not simple and homogeneous like timber but has concrete bones, iron ligatures, and a cement skin.

Steel frame structure on the other hand is homogeneous in substance like timber but requires a skin in the form of paint or some other protection against water vapour, and its expansion and contraction must be allowed for in design. Apart from these properties steel framing is "carpentry" and should be recognised as such in design. Modern requirements for railway stations, exhibition buildings, and structures for commercial assembly, require steel carpentry apparently elaborate but resting upon the principles we have enunciated. The expansion and contraction of steel with variations in temperature makes necessary "an expansion joint." In the fine roof designed by M. Garnier for his cattle-market at Lyons (Fig. 104f), the "expansion joint" is in the form of a steel hinge at the apex of each couple. This roof also shows a common-sense design in the matter of glazing. The roof covering is a series of decks having vertical glazing between them. By this means the glass remains cleaner and is more efficient than when laid horizontally. Proper access for cleaning a large span roof is an important factor in modern design since the efficiency of top lighting depends upon cleanness.

It is rare that architects are themselves sufficiently highly trained in the

¹ Also steel and concrete design was rendered possible owing to the fact that the coefficient of expansion of the two materials happened to be nearly the same.

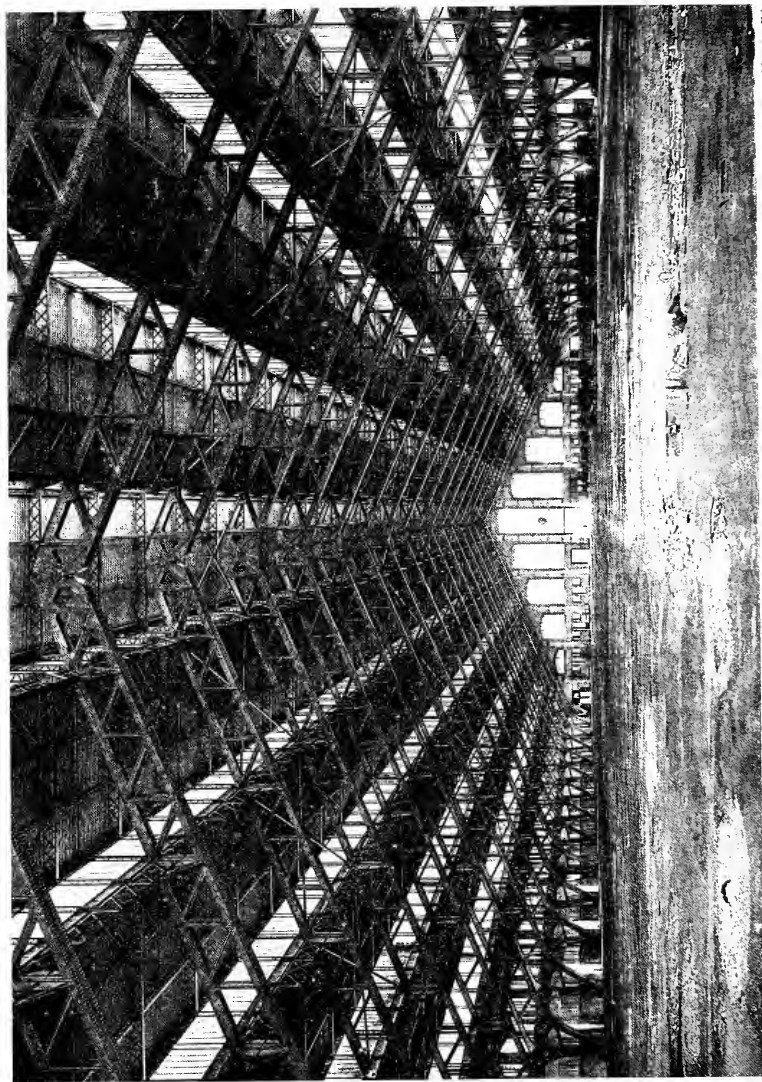


FIG. 104f.—LYONS, CATTLE-MARKET AND ABATTOIR. (By Tony Garnier.)

[Cliché, Ch. Massin, Ed.]

technique of steel structures to undertake a large span building on their sole responsibility. This is not surprising owing to the enormous range of the responsibility falling upon the modern architect. But roofs have been, and remain, the province of the architect and he should strive for the complete mastery of structure necessary to their design, and to their expression (*see also* x. 6).

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ROOFING MATERIALS FROM A WINCHESTER PSALTER. TWELFTH CENTURY.

Chapter VII

ROOFS (*Continued*)

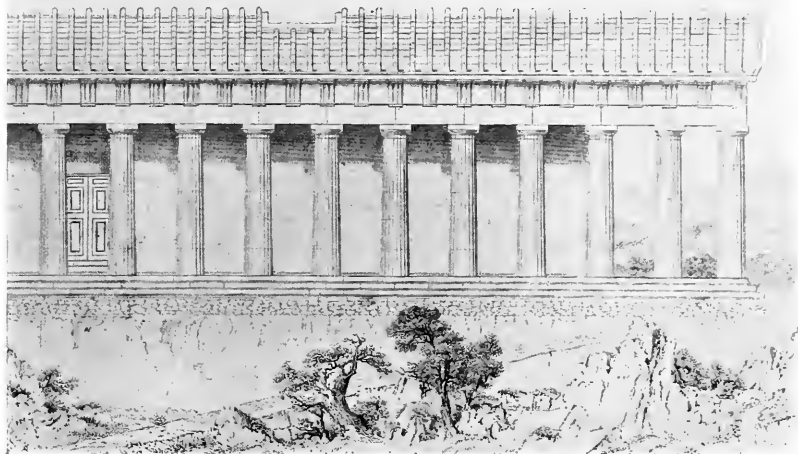
1. GREEK MARBLE TILES

WE must now examine some of the effects on shape of the permeability of the roofing material.

Greek temples were generally to be seen from an angle view and at a distance, as well as close at hand; the roof though low in pitch (about 15 degrees) was visible, and had considerable beauty (Fig. 105). Its characteristic texture was given by the fine tiles, moulded, or laboriously cut in marble, and forming an elaborate system of waterproofing. Marble tiles are specially mentioned by Pausanias as something of a wonder; and as a deliberate imitation in marble of earthenware forms.¹ There was obviously expended on them the kind of invention in water-

¹ "And the tiles on the roof (of the temple at Elis) are not of baked earth but Pentelican marble to imitate tiles. They say such roofs are the invention of a man of Naxos called Byzes." Pausanias, *Description of Greece* (v. 10).

proofing that is now lavished on window design in exposed positions, and they reveal the ground of craftsmanship always underlying Greek architecture. But they were evidently looked upon as a luxury and there is no evidence that their superior waterproofing value lowered the pitch of the roof.¹ The roof of the temple at Aegina had tiles in earthenware and marble similar in shape—the marble



[From Cockerell's *Aegina and Bassae*.

FIG. 105.—EAST FLANK. TEMPLE OF APOLLO AT PHIGALEIA, NEAR BASSAE.

tiles forming a margin upon eaves and pediment. (1) The ordinary tile system, as seen (in marble) in the roof of the Parthenon (2) and (in terra cotta) at Selinus in Sicily (3), consisted of butting together lines of large tiles either straight upon the heavy rafters or else upon wood sheathing (as in Philo's specification) (vi. 8) in such a way as to form regular straight joints from ridge to eaves. These joints

¹ There is only a difference of less than two and a half degrees between the pitch of the roof of the hexastyle archaic temple of Ceres at Paestum, roofed in earthenware, and the pitch of the roof of the fully-developed hexastyle temple of Apollo at Phigaleia, roofed in marble. Some figures for the pitches of Doric temple roofs are given in *Appendix, Note 6*.

were themselves shielded by smaller gable-shaped tiles known as *barmoi* or joint tiles. These *barmoi* gave the marked lines characteristic of the Greek roof; the lowest tile in each line formed an *antefixa* or fastening and was dowelled into the cornice in order to prevent the rows of tiles slipping downwards under gravity. The *antefixa*, therefore, was appropriately emphasised by ornament (Fig. 86 and vi. 5). The full tile development, however, is found at the temple of Apollo at Phigaleia (1) where tile and cover tile, of marble throughout, are carved in one piece, and elaborately throated and grooved to prevent rain being forced in under wind-pressure (Fig. 105*a*). The tile proper extended from centre to centre of the rafters, a distance of 2 feet $1\frac{3}{4}$ inches, and was 3 feet $6\frac{1}{2}$ inches long, the joint portion projecting and lapping 2 inches. The thickness of the marble was only $1\frac{3}{4}$ inches and each tile must have been an immense labour. Parian marble, though not as durable as Pentelic was generally used, probably for the sake of its transparency. (2) Parian tiles only $1\frac{3}{4}$ inches thick must have admitted considerable light from overhead into the cell of a temple.

2. THE ROMAN TILE

The ordinary Roman tiled roof consisted, like the Greek (vii. 1), of earthenware pans or plates called in the Latin *tegulae*, laid in lines following the direction of the rafters, each pan resting upon and overlapping the one below it. A rebate¹ often prevented the upper pan sliding down upon the lower. The lines of pans were butted together and the straight vertical joints thus formed were covered in turn by the *imbrex* or joint tile (Greek, *barmoi*), semicircular in section. The *imbrices* were tapered so that the lower end of one covered the upper end of the one below (Fig. 106). The lowest *tegula* and *imbrex* supporting the weight of

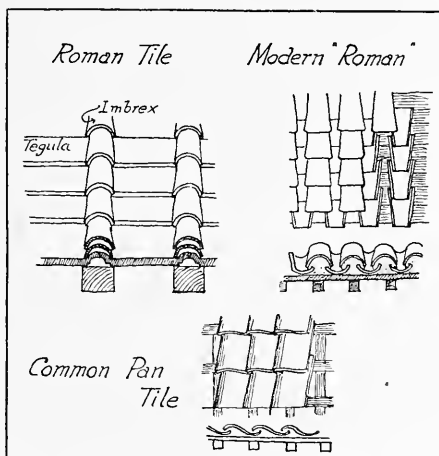


FIG. 106.—EXAMPLES OF ITALIAN TILES COMMON TO ALL PERIODS.

¹ See example in British Museum.

VII. 2. Theory and Elements of Architecture

all those above it in the same line, were held, as in the Greek roof, by the antefixa or by some device similar in principle. This principle of supporting the lines of tiles from below is different to the method employed for the slate, or

for the small modern tile, of pegging or hanging up each tile to the batten or board beneath it.

Several variations of the Classic Roman tile have been developed or may always have existed. By using a semicircular section only, both for *tegula* and *imbrex* the modern so-called "Roman tile" is produced. The common English pan-tile of to-day is simply a rough method of combining tile and joint-tile in one piece as



FIG. 107.—MILAN. ST AMBROGIO.

had been done by the Greeks in marble at Phigaleia (Fig. 105*a*). The usefulness of the Classic tile has caused a certain continuity in architectural history. For instance the tiled roof, a characteristic both of the Roman *domus* or private house and of the early Christian churches, is found almost unaltered in the Romanesque churches of southern France (4) and is characteristic of any Italian town to-day. The Roman *domus*¹ consisted of a series of rooms giving upon internal courts and gardens pleasantly grouped and roofed and surrounded by a wall in which there were sometimes a few windows, but which generally gave a retired or cloistered impression. Externally the tiled roofs, not steep in pitch, must have given the general character, to which was added occasionally a view tower or campanile (Fig. 108). The group gives an appearance not unlike that of an Italian church. But within the enclosing walls the roof played a more important part still during the early years of Christianity. There are several

¹ The *domus*, or private house, must be distinguished from the *insula*, or block of flats.

similarities between the plan of the typical *domus* and the plan of the early churches, the most noticeable being the atrium court at the entrance end. It was probable that the Roman method of collecting rain-water in the impluvium tank (5) in the atrium or entrance court of the Roman house, led to the practice of baptising in that court and eventually to the emerging of the baptistry at the western or entrance end of the church. The baptistry building of an Italian town, west of the *duomo*, to which all the babies are still carried, maintains in its uses and structure something of a public and initiatory character. Thus the roof continued to influence the plan, and the theologian and the domestic builder combined to produce familiar forms. An early church like St Ambrogio at Milan still possessing the atrium unspoiled (Fig. 107), suggests the true value of an entrance chamber in the design of a church, and in respect of its tiled roof and plain unornamented walls suggests also the external appearance of the Roman *domus*.

3. SLATES AND SHINGLES

In northern countries the stone slate, more suited to a steeper pitch of roof, seems to have had a development parallel with the tile from early times. The Romans in Britain were subjected to our climate for four hundred years; it is not surprising that in roofs, as in many other things, they developed a northern usage. The Romano-British slate, as found on ancient sites in England and Wales, was an elongated hexagonal about 11 inches wide and from 16 inches to 18 inches long. (6) A single nail-hole, varying in position, held the slate upon a boarded or wicker-work roof. In appearance these slates gave a lozenge pattern

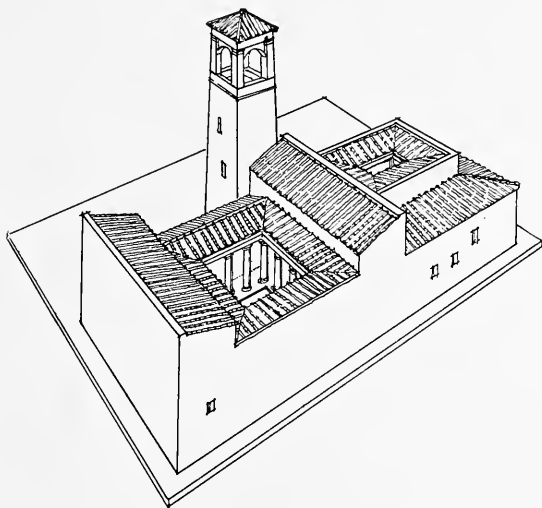


FIG. 108.—ROMAN "DOMUS," WITH VIEW TOWER.

exactly resembling some of the forms of the twentieth-century asbestos tile. In

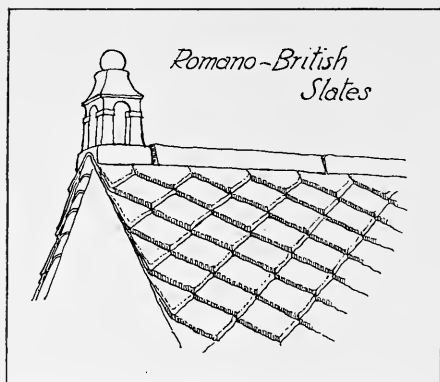


FIG. 109.—LLANWIT MAJOR, GLAMORGANSHIRE. RESTORATION OF A ROMANO-BRITISH SLATE ROOF. (After J. Ward.)

the case of the lozenge-shape slate or tile the water runs down the verges and, collecting at the point of each slate, is delivered upon the centre of the slate below. A disadvantage is that special slates have to be made for eaves and ridge. The twentieth-century asbestos tile looks light and unstable owing to its thinness; this was not the case with the Roman slates cut from "Stonefield" limestone or from Pennant flags. An interesting Roman roof ridge and gable finial were found with the hexagonal slates, at Llanwit Major in

Glamorganshire (6), a restoration of which by the late J. Ward is given in Fig. 109. The ridge consisted of lengths of Bath stone having a flat top 6 inches wide and sloping sides about 4 inches. The gable finial, a graceful diminutive cupola was also of Bath stone corresponding with the ridge lengths. Several such gable finials exist. "These terminations are late derivations from acroteria and prototypes of gable crosses; they are links in a continuous chain from Greek to Gothic." (7)

Slate, a term now confined to the product of rocks having slaty cleavage, was originally used for any stone slab. Welsh slates were used by the Romans and intermittently ever since. They were specialised in the nineteenth century and spread by the railways.



FIG. 109a.—TENTERDEN, KENT. SHINGLE ROOF AT ORIGINAL PITCH.

[H. B.]

In the Middle Ages, as revealed by the illuminated manuscripts in the British Museum, all kinds of slates, tiles, and metal plates were common, as illustrated in the headpiece to this chapter.

Shingles or small wooden slats were much used in the eleventh, twelfth, and thirteenth centuries as a roofing material (8) where timber was abundant. The church of Tenterden in Kent (Fig. 109*a*) has had no other "thack" but shingles and preserves the original high pitch suitable for that material. Shingles are frequently used in America to-day as a roofing material. They are laid in the same manner as slates but can be easily nailed to the battens beneath. They should be an inch thick and tapered to one end. They are useful for roofing spires and other buildings having a steep pitch owing to their lightness. They are also used upon windmills. "In England in the eleventh and twelfth centuries the houses were roofed with stone shingles or tiles generally oval shaped having a nail hole in the upper part." (9) The surface covered with hexagonal or curved shingles presents a scale-armoured appearance; this has been imitated in stone on the coping of the buttresses of Lincoln Cathedral. The same imitation of fish-scale or scale-armour is found in Classic times in the marble roof of the Monument of Lysicrates at Athens.

4. CHANGE FROM SHINGLES TO LEAD IN THE MIDDLE AGES

As the medieval roof increased in height from the Romanesque to the high Gothic the lightness of wooden shingles must have had an obvious advantage. Salisbury Cathedral at its completion in 1258 was first covered with shingles from the Bramshaw woods, New Forest (9), and probably many other large churches likewise. But in the thirteenth century, lead which had been used sparingly in the eleventh and twelfth centuries (8), owing to its cost, began generally to supplant tiles and shingles for important buildings in England and France. The lead was heavier and required special fixing in position on heavy battens by means of strong lead clips (Fig. 109*b*); also it expanded and contracted with the heat and since its water-proofing value was much greater it could have been used easily at a much lower pitch. Yet the use of lead did not check the tendency to a steep pitch. The lead sheets of the high-pitched cathedral roofs of the thirteenth century must have "crept" and caused trouble as they do to-day.¹

¹ Lead sheets upon roofs are said to "creep" when by continuous expansion and contraction they work themselves loose into a series of folds, and have then to be re-cast. Length of life depends largely on aspect. A portion of lead roof over north aisle of Canterbury choir, shaded from the sun, has not

VII. 5. Theory and Elements of Architecture

The reason so important a structural change caused no immediate corresponding shape change was the operation of the third of the great formative factors in roof design given at the opening of this narrative (vi. 6). The high Gothic roof had become more than a structural necessity—it had become a shape delighted in by people for its own sake.

5. FRENCH GOTHIC—THE ROOF AS A SHAPE

It has been shown that French medieval engineers developed the timber-roof truss and made possible the high timber roof above the Gothic vault (vi. 10),

and at the same time the roof of the medieval cathedral in France and England was covered with lead at an angle the least suitable for that material (vii. 4). These facts are the symptoms, in building, of the great cultural movement of the thirteenth century, in which France led Europe. This movement, owing to a combination of circumstances, was peculiarly fitted to be crystallised in the architecture of the time, of which the French roof, as we shall see, was the characteristic element.

As a movement it was both humanist and democratic; and it happened to coincide with powerful developments in the growth of organised religion. The sterner feudal and monastic order, represented in architecture by the Benedictine monastery and the Norman



H. B.

FIG. 109b.—CANTERBURY CATHEDRAL. OLD PART OF THE ROOF OF THE S.E. TRANSEPT SHOWING UNDER SIDE OF THE LEADS, AT ANGLE OF 50°.

keep, had yielded before an alliance of the townspeople with their bishops, and before the refining influence of Madonna worship. The four great been leaded since *circa* 1500. On the south-west transept the leads cast in 1793 are already (1926) showing cracks and stretchings. In Fig. 109b note the absence of close boarding.

churches of Paris, Chartres, Reims, and Amiens were all dedicated to the Madonna, *Notre Dame*, and raised by popular efforts in which all joined with a new enthusiasm.¹ The University of Paris was founded in 1224, and drew Roger Bacon from England, and Thomas Aquinas from Italy. The movement was intellectual as well as popular. Theology, the preoccupation of the best minds of the time, dominated all other activities. Astronomy, nature studies, law, medicine, art, and festivity, were all gripped and made part of an elaborate intellectual system having a sharply defined concept of God as its apex. Theology precipitated all the ideas of men into clear images easily grasped and communicated. Belief in God and consent in the system gave, in religious affairs, a single Intelligence to the European community. This Intelligence, at its highest, could be directed to a magnificent worship, or at its lowest to the cruellest tyranny. But it could be expressed wholly and clearly in a building like a great cathedral. Architecture at that epoch possessed an advantage never afterwards equalled. In architecture a common field was provided for all those activities which theology had made orthodox. Priest, architect, painter, sculptor, stone-worker, tapestry weaver, musician, and mummer, were all enlisted in the building and functioning of a large church. The great system produced great artists; more than that, the nature and power of art was understood by the priests, and by the masters of ritual, who used the cathedral as a sacred theatre. Art and craftsmanship was in demand for every purpose sacramental and utilitarian. Thus the great roof of Amiens raised by the builders, served upon the horizon to hearten the pilgrim and waited always for the sinner living within its view. The Last Judgment carved in the tympanum of the western porch, chastened and delighted the citizen who had contributed funds towards it. The child learned Bible stories from the painted windows. On all hands, in the absence of the printing press, the communication of ideas was by visible imagery. (10)

In the cathedral, moreover, all this imagery was organised and linked.²

¹ "At Chartres the people, and even the nobles, harnessed themselves in long lines to the carts loaded with building materials and provisions for the workmen. Preceded by a banner they dragged enormous weights in silence, fording the streams on their way, and at each stoppage priests confessed the penitent and exhorted the pious." (West's *Gothic Architecture in England and France*, 1911, p. 25. See also translation of Abbot Haymo's letter in Porter's *Medieval Architecture*, 1909, vol. ii., p. 151.)

² "Thus in the façades of Laon and Paris, finished about 1220, the dominating idea is the opposition between the Natural Kingdom and the Kingdom of Grace. The programme of Notre Dame de Chartres, represented by the 10,000 figures of her 125 great windows and by the sculpture of her two lateral façades, is a complete exposition of the whole of the doctrine of Christianity comparable to the great *Somme de Theologie*, which St Thomas Aquinas was to compile some years later." (10)

Enclosing and dominating all was the vault at an extreme height: ordering the whole plan by its construction (v. 7). And protecting the vault was the roof.

Now the planning of a large church to suit an elaborate theological programme, must have required special knowledge, and it is not surprising that the names of great architects emerge at this period.

The French architect of the thirteenth century, unlike his monastic predecessors, was a layman. He was a specialised master-builder, who studied the rapid advances in vaulting and at the same time knew how to draw plans and geometrical figures. (11) He travelled in order to increase his knowledge. The accommodation and management of crowds of pilgrims and the planning of religious and secular buildings to receive them must have been his special study.¹ The building of Chartres, begun 1194, served as atelier and experiment station for the new school of builders. Jean d'Orbais began the choir at Reims in 1211, to a design which had to satisfy the requirements of the French coronation ceremony (Fig. 110). His plans were adhered to by his successors. "The merit of Jean d'Orbais was that to elements created at Chartres he gave an organic unity." (10) In 1220, Robert de Luzarches began the western end of Amiens. Architects in those days received small pay, but they had a special privilege. Side by side with kings and bishops they were permitted burial in the churches they had designed. In Reims there used to survive the tomb-

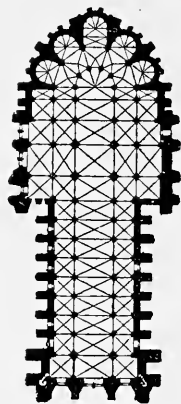


FIG. 110.—PLAN OF REIMS.

slab of Hue Libergier planner of St Nicaise.² On this slab the architect was depicted holding a model of his church in one hand and measuring rod in another. Below were a square and pair of dividers; over his head was an arch conventionalised, and a pointed roof—crown and emblem of his art (Fig. 111).

Externally the roof gave to the French cathedral its distinctive silhouette. This silhouette is important. It is the silhouette that tells when daylight is thin and the northern element asserts itself in our climate. A certain pagan

¹ All great churches relied for funds upon the offering of pilgrims: hence the competition for "Relics."

² A large church at Reims, contemporary with the cathedral, but destroyed in the eighteenth century.

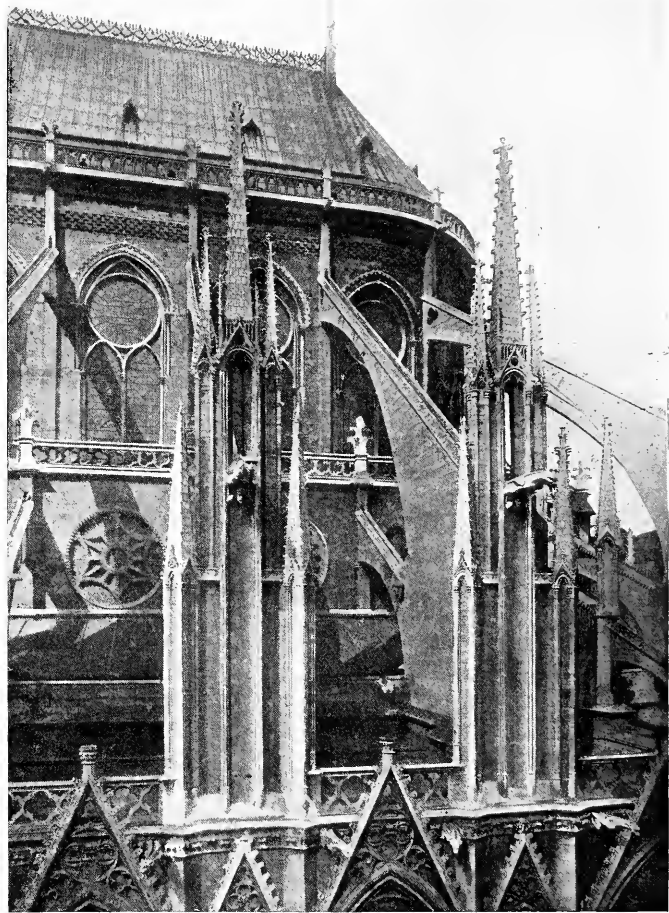
exorcism also is present in the gargoyles, grotesques, and *stryges* of the Gothic roof.¹ Fear is present—fear permitted and made orthodox. But it is not only in fear that the pagan element is to be seen. These French cathedrals are not more northern than the vine. A certain primal riot and naturalness is traceable in those shapes that look out across the vineyards of Champagne and Burgundy. There is also æsthetic refinement of a high order. The artist is dominant here, but he works not by elimination as did the Greeks, but by including all possible opposites, touching them and harmonising them. The immense roof ridge running horizontal across the forest of pinnacles, as shown in our illustration (Fig. 112), was a powerful instrument for harmonising and unifying. There was always present, however, in the French Gothic church a disruptive tendency—a tendency towards vertigo and instability. The vault and roof of Beauvais finally summed up and destroyed Gothic architecture. Beauvais' vault is 160 feet above the pavement, the ridge of the roof 220 feet above the ground; above that again rose a large *flèche*. In 1284, twelve years after its completion, the choir vault fell. It was rebuilt, but in the sixteenth century the *flèche* was struck²



FIG. 111.—HUE LIBERGIER, ARCHITECT OF ST NICAISE, REIMS. (*Audsley's Dict.*)

¹ Compare the dragons on the roofs of the Norwegian timber churches (Fig. 11).

² De Baudot et Perrault Dabot. *Les Cathédrales de France* [Schmid et Laurens or Massin.], Vol. i., p. 23.



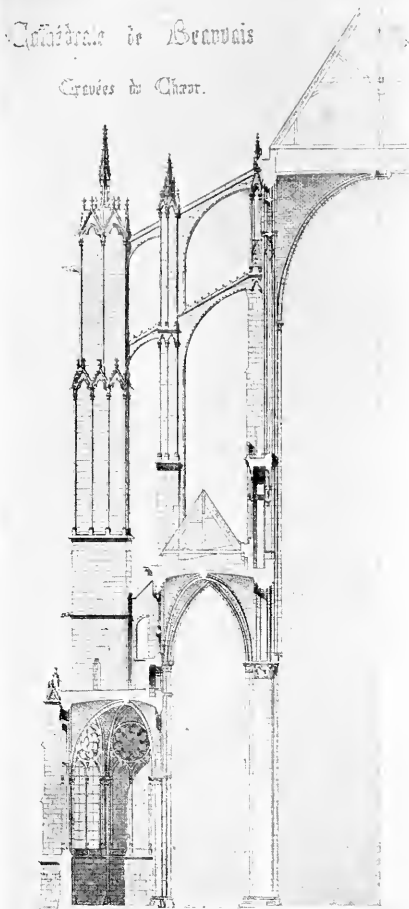
[Gliché, Durand.]

FIG. 112.—PARIS. NOTRE DAME. ROOF OF CHOIR. (*Archives de la Commission des Monuments Historiques. Cathédrales de France.*)

by lightning and fell, bringing one of the transepts with it. The building of the nave was not even attempted owing to the magnitude of the task. The church to-day (Fig. 112a) remains a fragment only, comparable to any great historical monument whatsoever, but a ceaseless legacy of anxiety on account of its structure and artistically an emblem of the unattainable.

6. THE RENAISSANCE SITUATION

When we turn from the religious aspect of medieval building to the domestic, there is apparent quite a different state of affairs. Hygiene had not been envisaged by Christian theology; the Jews preserved the rules of health of the Old Testament as part of their religious observances, and in consequence suffered less during the Black Death than did the Christians. Now in northern climates, where the sun is not all powerful, where life is conducted under a roof rather than under a colonnade (ii. 1), where overcrowding in narrow chambers tends towards warmth and towards disease, then the lack of any study of hygiene in a great system of culture with the resulting increase in disease and death must produce specific results. One result was to make sensitive minds dissatisfied with



H. Chainé del.]

[Cliché, Ch. Schmid et H. Laurens, Eds.]

FIG. 112a.—BEAUVAIS. SECTION THROUGH EAST END.
(Archives de la Commission des Monuments Historiques.
Cathédrales de France.)

VII. 6. Theory and Elements of Architecture

existing conditions and ideas and disposed to welcome new. In medieval city-dwellings, roofs increased in height partly owing to the fact that attics were cheaper than heightening the walls. Undoubtedly the conical and penthouse



FIG. 112b.—NORDIC ROOF DWELLINGS AS DEPICTED BY DÜRER.

roofs, the projecting gables, windowless towers, and lines of dormers and garret dormers¹ have caused some of the most picturesque building groups, and some of the worst housing conditions ever known. It was from such dwellings in Rotterdam and Heidelberg, in Oxford and Cambridge that humanist students like Erasmus, educationalists like Colet and Luther, painters like Dürer, and poets like Celtes towards the end of the fifteenth century, began to sigh for light as well as for enlightenment. Dürer sets his "Prodigal Son," when about to arise and return to his Father, in a German farm-yard surrounded by the most monstrous nordic roofs (Fig. 112b). The title of an early

sixteenth-century German ode by Conrad Celtes runs as follows:—

"To Apollo praying that he would come to us from Italy bringing his lyre with him."²

Now the Renaissance was an Italianising movement but it was much more. All the humanist, light-loving, sun-deprived elements in the northern races moved out to meet it. But there were two fields in which conflict was inevitable,

¹ In Loggan's *Cantabrigia Illustrata*, 1690, a row of upper or garret dormers can be seen in the roofs of Queens' College and Pembroke College. In Pembroke College a few garret dormers still remain (1925).

² Celtes, "*Ars Versificandi*," 1486. (Cited by Pater, *Imaginary Portraits*, p. 142.)

in theology and in architecture. In these fields opposite systems of equilibrium were brought by the new movement into competition. In architecture the two systems are those which we have been analysing and which can be summarised and distinguished as the "Wall" or mediterranean system, and the "Roof" or nordic system.

Now each system, as we have seen, had inherent in it some of its opposite ;¹ but each had already produced a fine flower or image of itself in response to different climatic conditions and to a different figure in the human mind. These—the "Classic" and the "Gothic" each so complete and corresponding to such profound, but diverse, needs must always tend by their very mastery to stress the opposition of each to each.

At the period called "Renaissance" the new-comer was not the Roman or Greek concept revived, but the strong nordic spirit reaching beyond ecclesiastical authority towards its own naturalism and humanism. It was in spirit a migration towards the sun—the last of the nordic invasions.

But it was stimulated by contact with the immense plastic talent of Italy, a talent potential in all periods. The early Renaissance appeal to antiquity was really an appeal to reason and was not at first as strong a factor as the appeal to nature.² But in architecture this "reason" was embodied in the great Roman forms which, in their fragmentary condition, were still standing in Rome in the fifteenth and sixteenth centuries in far greater numbers than are to be found to-day.³ Now we have already noted (v. 2) the particular scenic quality of Roman "wall architecture" (Fig. 54). This quality appealed to artists quite independently of any intellectual element. Antiquity hung above them in a series of magnificent shapes, which they set about measuring and drawing. Thus it came about that the beautiful medieval naturalistic art of Burgundy, Florence, Lombardy, the Loire,⁴ fertilised by the "Classic" but still richly northern (Fig. 112c), soon had a rival in the actual Roman walls and columns standing in

¹ For instance the "*architecture of the wall*" contains also the pointed element in the shape of the pyramid; and the "*architecture of the roof*" gives examples in England of the flat, or "bearer" roof, resembling that of Greece (p. 180).

² "With Alberti the appeal to antiquity is little more than a fashion of speech. At other epochs, when men have suddenly broken loose from some old-established authoritative system, they have turned to the classical world for the support which its sane and rationally based intellectual and political systems seemed to offer." (Baldwin Brown's *Introductory Essay to Vasari on Technique*, 1907, p. 11).

³ Numbers of Roman structures were sacrificed in order to provide travertine, marble, and lime, for the re-building of St Peter's. (Lanciani's *Wanderings Through Ancient Roman Churches*, 1925, p. 100.)

⁴ For examples of this phase of the Renaissance compare also Figs. 112b, 113a, 141c, and 141d.

vii. 6. Theory and Elements of Architecture

Rome. These Roman walls and columns and the style they exhibited with such superb effect appealed to Italian ecclesiastical pride and it was not long before

the "Classic manner" was made an authority as absolute as any that had preceded it.¹ Thus the "architecture of the wall" came into conscious opposition to the "architecture of the roof" and the term *Gothic* was invented² implying a criticism.

The roof, however, embodying as it did the immense medieval force and culture which we have analysed (vii. 5) was not an element easily dissolved. The conflict between the wall and the roof can be followed in the comparative study of Renaissance building forms. In Italy, as we have seen (v. 6), the wall element had always been strong and the Roman tradition had endured throughout the Middle Ages in certain characteristics of horizontality and dead-load

structure. In Italy, therefore, the high-pointed Gothic roof, as at Pisa and

¹ Classic architecture became identified in the new St Peter's with the Counter-Reformation, and with a definite system of equilibrium in theology.

² The word as applied to medieval pointed architecture is said to occur first in Vasari's treatise on Technique: "We come at last to another sort of work, called German, which . . . is very different from the ancient and modern. . . . This manner was the invention of the Goths." Raphael had previously used the term, "but makes it quite correctly belong to the actual era of the Gothic conquest of Italy in the fifth century." (Baldwin Brown's *Vasari on Technique*, 1907, p. 134.)



FIG. 112c.—GENOA. PALAZZO D'ORIA.



FIG. 113.—LA MOTTE GLAIN. FRENCH ROOF COMPOSITION.

VII. 7. Theory and Elements of Architecture

Orvieto cathedrals—never a climatic necessity—disappears and its place is taken by the massive Roman cornice, with its balustrade, blocking-course, and other treatments devised to give an outline and a finish when the roof is lacking.

In England, where the climate was an alternating quantity (ii. 6), the medieval roof, as we shall see (vii. 8), had been lowered in pitch by the Perpendicular builders for the sake of economy and in response to the needs of lead

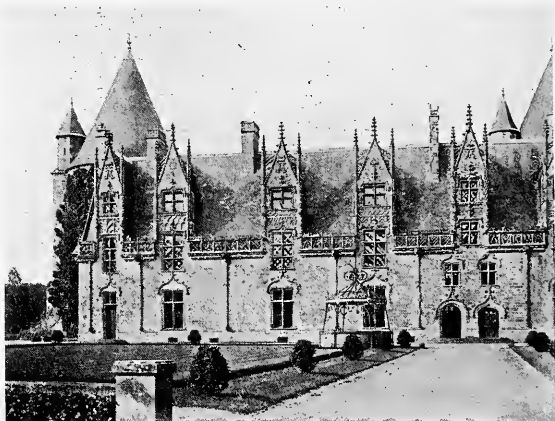


FIG. 113a.—CHATEAU DE JOSSELIN.

as a covering, we find that the roof treatment of the English Renaissance builders became indeterminate and alternating, sometimes pitched high sometimes low. This alternation of roof treatment has continued in England down to the present day (vii. 8).

In France, however, where artistically the northern genius was at its strongest and the roof at its highest, a complete æsthetic fusion of the wall and roof was arrived at, and the two used in a consummate art to enhance each other.

7. FRENCH RENAISSANCE ROOFS—THE SILHOUETTE

The French have used their roof for a definite artistic purpose at all periods of their history. This purpose is the silhouetting or outlining of the mass of the building.

A well-marked roof completes and defines a building. This is specially the

case in climates where the sky is the only bright field and where little or no light is reflected from the ground. The French builders made the finest compositions against the sky out of the simplest roof elements—as for instance at La Motte Glain (Fig. 113).

A well-marked roof helps to unify a complex design. We have seen that the French builders used the lofty horizontal expanse of the roof to dominate the buttresses and pinnacles of the Gothic cathedral (Fig. 112). In secular building they used the same methods. The elaborate pointed dormer windows of the Louis XII. wing at Blois (1503) or of the chateau of Josselin (Fig. 113*a*) are contrasted against, and ruled by, the plain roof surface behind. At the chateau of Fontaine Henri (Fig. 114) and in the Chateau d'O near Mortrée, the roof above eaves level is half the total height of the building. The upper parts of these roofs show no dormers and must be quite useless; they could well have been cut off at half their height were it not that their artistry is obvious. They control and harmonise the various masses beneath them. In the period of Francis I. this control was sometimes threatened by the profusion of dormers, cupolas, and decorative chimney stacks. At Chambord (Fig. 115) the design consists of a huge elaboration of roof forms above some strongly-marked horizontal wall lines. The contrast is remarkable but not beautiful.¹ But in the finest early Renaissance buildings the roof is kept firm and simple, as at Azay le Rideau. In this beautiful chateau a French builder has shown that he has learned all that the Italians could



FIG. 114.—CHATEAU DE FONTAINE HENRI.

¹ In the opinion of some the contrast at Chambord is disastrous, as though a village were built above a fortress.

teach of symmetry and order and that he could make the finest deliberate composition using medieval masses (Fig. 116).

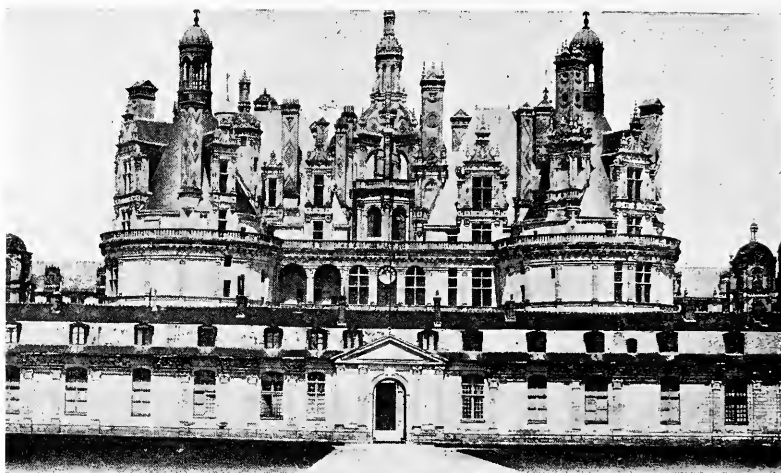


FIG. 115.—CHATEAU DE CHAMBORD.

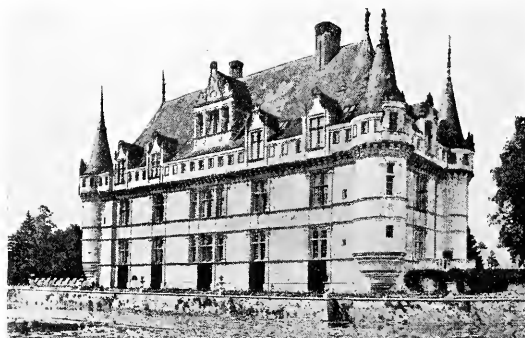


FIG. 116.—AZAY LE RIDEAU.

Both French and English medieval builders were masters of grouping, but the French used their roofs deliberately in order to emphasise plan shapes. When in Renaissance times the plan was made symmetrical, the French roof was used with great skill to express the grouping of the various wings of the building. The

Chateau de Maisons near Paris, by F. Mansart, is not one building but three grouped about a central axis, each mass having its own roof but the whole

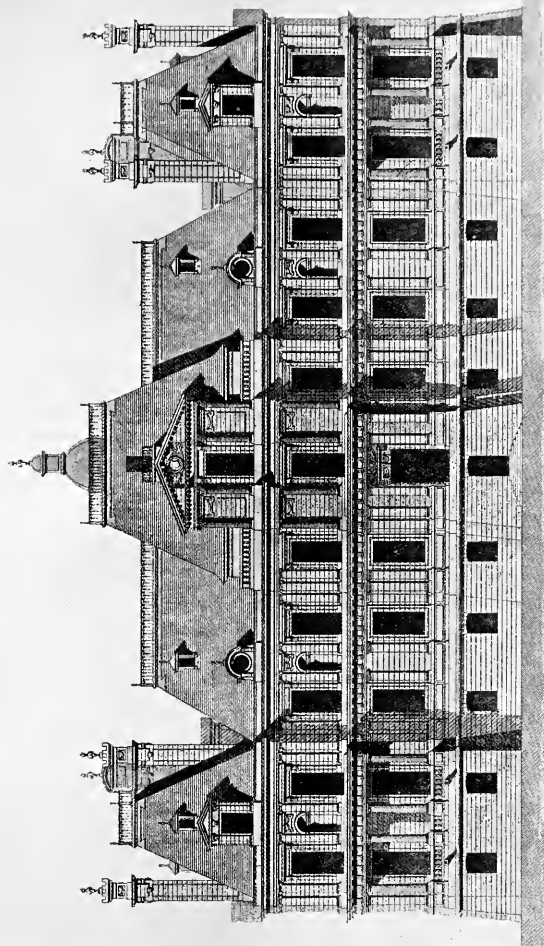


FIG. 117.—PARIS, CHATEAU DE MAISONS SUR SEINE, FRONT TO THE RIVER. (From Sauvageot.)

VII. 7. Theory and Elements of Architecture

roof treatment uniting all the parts into a single whole (Fig. 117). At the Chateau de Balleroy (Fig. 117*a*) the same methods are used upon a group of five parts.

The value of the roof in emphasising plan shapes can be well realised when it is absent, as in the English example shown in Fig. 118.

Sometimes roofs of different pitch were employed in the same building to emphasise or subordinate the parts (Fig. 118*a*). These group-plans were originally quite simple in their units, one room led into another and the partition wall was not a factor in the problem. They were, therefore, easily embodied and refined as pure shapes. In the buildings of this kind of the sixteenth and seven-



FIG. 117*a*.—CHATEAU DE BALLEROY.

teenth centuries in France, the purely plastic element in architecture reached its highest point. It is not surprising that their rich variety and beauty and the talent of the artists who created them, was able to draw Leonardo da Vinci from Italy to the banks of the Loire.

The French architect, J. H. Mansart, in the eighteenth century took all the elements of the Gothic church—high-pitched roof, buttresses, arcades, and apse, and yet made of these elements a Renaissance building. The result is the wonderful chapel at Versailles (Fig. 119), a synthesis of “roof architecture” and “wall architecture”—the triumph of the peculiar genius for blending of the French architect.

The French, making the most of their climatic conditions, frequently emphasised their roof even in their most classical designs. The “Mansart roof”



FIG. 118.—PLAN SHAPES WITHOUT THE EMPHASIS OF THE ROOF.



FIG. 118a.—PLAN SHAPES EMPHASISED BY ROOFS OF DIFFERENT PITCH.

VII. 8. Theory and Elements of Architecture

having different angles in the same roof gives greater accommodation and makes a fine finish to a Classic building, as in the examples given from Blondel (Fig. 120).

In modern practice roof construction no longer presents the difficulties it did in former days. Either flat roof or high-pitched roof can be built equally water-tight, and — taking all factors into consideration — equally economically. The danger is therefore, that the roof should be either ignored or over-emphasised (Fig. 121). But the lesson of French architecture generally is the recognition of the roof as an appropriate form under northern climatic conditions, and its bold treatment in all types of building.



FIG. 119.—VERSAILLES. ROYAL CHAPEL. (By J. H. Mansart.)

8. ENGLISH ROOF TREATMENTS

In medieval England the economy ultimately to be had by lowering the pitch of the roof when covered with lead was not to be resisted. This lowering did not occur at once; churches had their roofs for generations covered with lead at the same pitch as for wood shingles (vii. 4). But after the Black Death, in the fourteenth

century, new roofs were built and the old re-built at a lower pitch. The older, higher, pitch can be traced on many a central tower to-day. This lowering was one of many economies which helped to produce the English "Perpendicular" style. The use of lead at a high pitch causes continual trouble

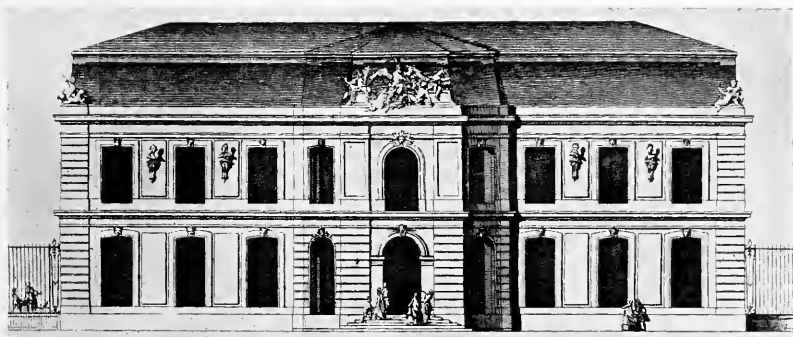


FIG. 120.—MANSART ROOF IN ELEVATION AND SECTION (Blondel).



FIG. 121.—ROOF OVER-EMPHASISED AND ROOF IGNORED.

owing to its weight and expansions and contractions (vii. 4), so that the English fifteenth- and sixteenth-century roofing practice was more logical structurally than the French. The lead roof to a gable was often designed at an angle of some 20 degrees, resembling the pitch of a Classic pediment, and at the apex the lead passed over a wide, smooth curve (Fig. 122) instead of a sharp ridge. To correspond with this tendency the arches of the window heads were flattened and frequently made horizontal. The Perpendicular hall and the Elizabethan façade become in some cases almost Classic in their horizontality. The wall, frequently brought up to a great height, was crowned with a balustrade or attic. Then the massive spectacular quality of a true wall style is seen as in the façades (apart from the grouping) of Bramshill (Fig. 123) in which the roofs are negligible. Bramshill, standing now almost forgotten in the retired county of Hampshire, breaks upon the eye with the strength and grandeur of a palace of the Cæsars—it is a kind of Shakespearian Classic, native to the soil of England, and produced in the same period as “Julius Cæsar” and “Antony and Cleopatra” in the drama.

On the other hand the fashion for elaborate Dutch gable-ends in England caused some notable Elizabethan and Jacobean roofs high in pitch. But in the country districts a quiet manor-house type persisted, in which the roof continued through the sixteenth, seventeenth, and eighteenth centuries at a pitch of 45 or 50 degrees (Fig. 124). Both these types were deliberately rationalised by architects—the gable-end type at Raynham Hall in Norfolk (1636), (Fig. 125), and the manor-house type by Inigo Jones at Coleshill, Berkshire (1650), (Fig. 125*a*). In the latter building the roof is both useful and of considerable artistic value,



[H. B.

FIG. 122.—CANTERBURY. CHAPTER HOUSE ROOF :
LEAD ROLLS PASSING OVER FROM GUTTER TO GUTTER.



FIG. 123.—BRAMSHILL, HAMPSHIRE.

[From Shaw's *Elizabethan Architecture*.]

the design is symmetrical and refined and at the same time carries forward the English domestic tradition.

Sir Christopher Wren recognised the true character of the English tile and slate roof and acknowledged it in his treatment. It is to be seen in the angle of his pediments. He seems just

to increase the Italian roof pitch for the sake of our climate. The result, in a building like Chelsea Hospital, is to give to a stately Classic design a touch of the provincial English (Fig. 126) with its own tradition and talent. Wren in more ways than one embodied the native English building genius.

In the eighteenth century, however, the Italian fashions for a while carried English architects quite from their moorings. The "Palladian" roof, low in pitch, and the small Palladian window (ix. 6) were certainly not suited to English climatic conditions. In the illustration (Fig. 156) in which a French and English mansion,

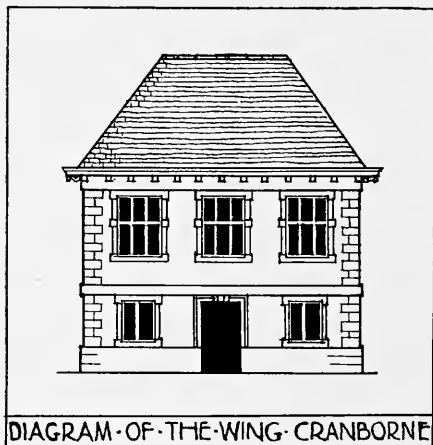


FIG. 124.—ENGLISH MANOR HOUSE ROOF TYPE.
(After Field and Bunney.)

each taken from a well-known book of designs, are compared, may be seen the difference between the roof and window treatments in the two countries. In both cases the French is more suited to the climate and is certainly more artistic.

In the nineteenth century the re-discovery of the artistic wealth of the Middle Ages, a movement of which the revival of Gothic was a part, again pitched up the



FIG. 125.—RAYNHAM HALL, NORFOLK.

English roof. First churches, then mansions, and then suburban roofs of all kinds took on the extreme medieval angle—regardless again of the suitable and of the economical. But the nineteenth century restored to English architecture the silhouette. There are times in our climate when only large masses boldly roofed are capable of “telling” as shapes (ii. 6). On those occasions buildings like St Pancras Station, Street’s Law Courts, Shaw’s Scotland Yard, and the new London County Hall by Mr Knott, having groups dominated by large roofs, are able to take advantage of the atmosphere and present themselves to the eye as fine masses.

But the English art of the group—peculiar to English buildings of all periods, requires a section to itself.

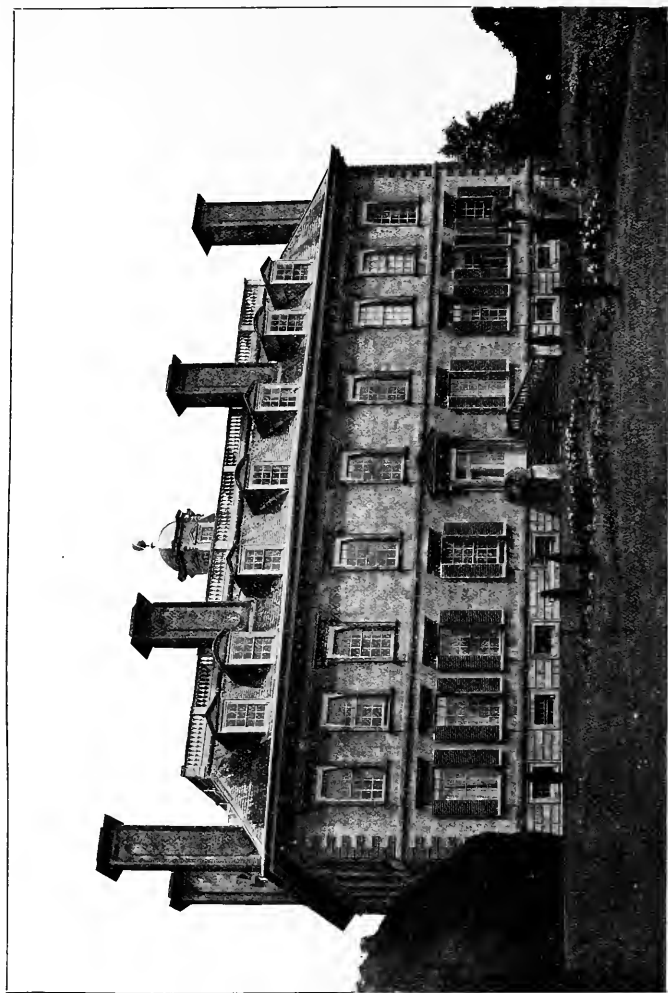


FIG. 125a.—COLESHILL, BERKSHIRE. (*Inigo Jones.*)

9. THE ENGLISH ART OF THE GROUP

We have seen that the English medieval church is different in plastic character to the French (vi. 4). In the English it is a group of halls dominated by a central tower rather than a single hall dominated by a lofty roof like the French. This was due doubtless to the persistent monastic character of the English



FIG. 126.—CHELSEA HOSPITAL. (Wren.)

[Photograph by W. F. Taylor.

cathedral; but the difference continues throughout architectural history. The French builders rely upon the roof to dominate the group, the English upon some vertical mass in contrast with the lesser horizontals. In Fig. 127, *a*, Salisbury Cathedral is shown in its simplest elements. The flank of the church is dominated by the great central tower which is able to control the two transepts. The flank is more interesting than the west end and has a unity of its own. Similarly each of our English cathedrals is a school in the grouping of masses. In Fig. 127, *b*, Lavenham Church in Norfolk is shown—a stately Perpendicular building having

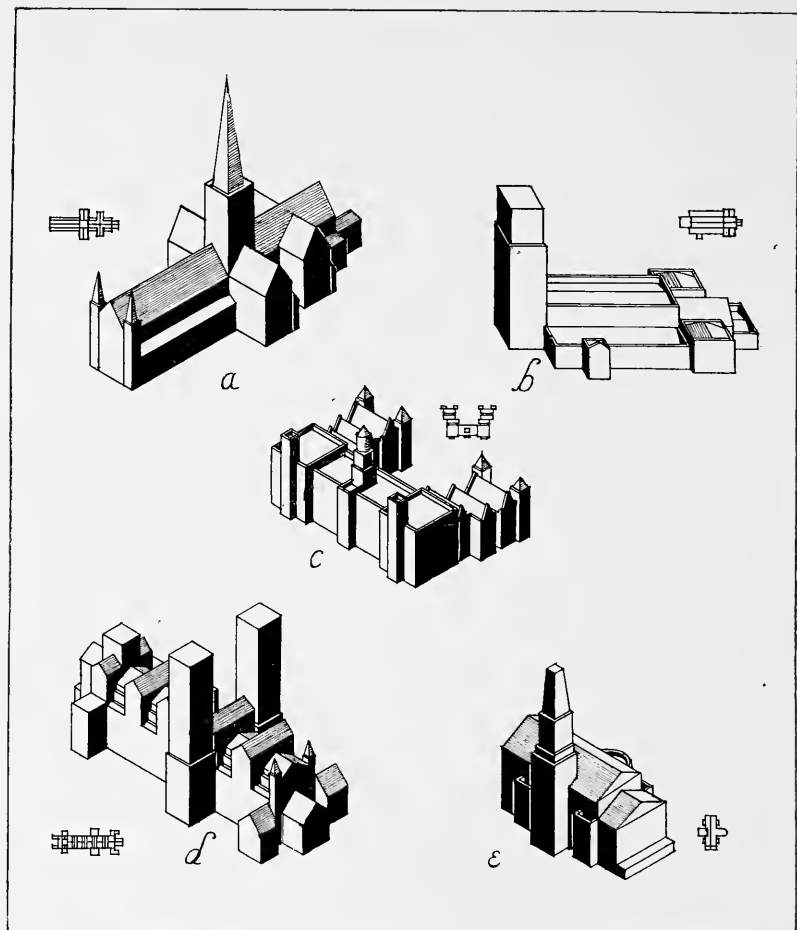


FIG. 127.—THE ENGLISH ART OF THE GROUP.

a Salisbury. *b* Lavenham. *c* Hatfield. *d* First design by Sir G. Gilbert Scott for Liverpool Cathedral. *e* St George's, Holborn.

all the characteristics of the English parish church type. These characteristics are a series of horizontal masses such as nave and aisles contrasted with uprights such as porches, and dominated by a tall western tower (Fig. 128*a*). The English Perpendicular churches of Somerset are also, like the Norfolk churches, fine examples of group design in England.

This medieval art of the group when ordered symmetrically by the English Renaissance builders produced the great variety and suggestiveness of the Elizabethan plans. One of the most complicated of these plans—Hatfield House—is shown in Fig. 127, *c*, reduced to its simplest elements. Here, although some pointed roofs enter into the design, the chief contrasts again are those of horizontals and verticals. The English builders were without the instinctive talent of the French, and though their plans are full of imagination their embodiments are less successful. Five examples of the most interesting are given in their simplest terms in Fig. 128 together with their plans.

This English art of the group is discernible in the work of Wren (Fig. 128*b*) and is found even in the eighteenth century in the middle of the Italian fashions where it is illustrated in the Church of St George, Bloomsbury, by Hawkesmoor (Fig. 127, *e*). Here the Classic nave and portico are dominated by a tall side tower. The lack of symmetry is negligible compared to the considerable unifying effect of this tower upon the design.¹ Another illustration of the English art of the group (Fig. 127, *d*) is Sir Giles Gilbert Scott's winning design for Liverpool Cathedral—now superseded. In this design the English group tradition for large churches is logically developed. The vitality is due to the familiar contrasting of verticals and horizontals dominated by two powerful uprights. Other relationships of this kind can be studied in the beautiful churches of Temple Moore, *e.g.*, the incomplete Church of St Anne Royton, Lancs. (Fig. 128*c*).

Thus the English art of the group persists to-day. Unlike the French grouping, it depends upon the multiplying and bold contrasting of large mass units unaided by roof emphasis. It is suited to modern thought and modern design, and is one of the achievements and contributions of the English Gothic revival.

¹ This church does not express its plan; the portico is on the south side and gives into the side of the nave; the real axis is at right angles to the apparent axis.

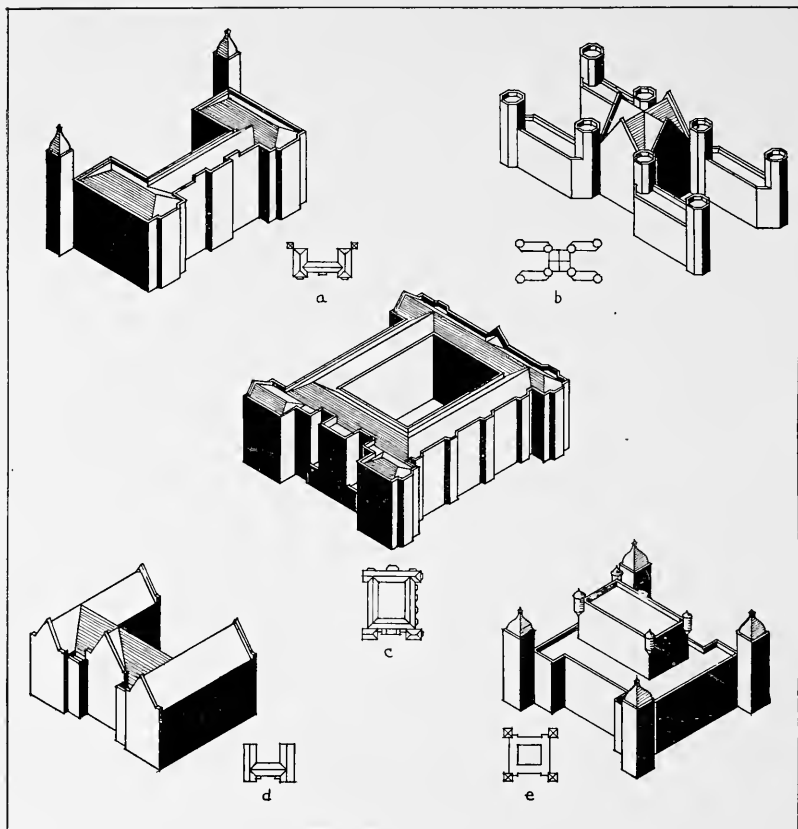


FIG. 128.—ELIZABETHAN GROUPING.

a Charlton House, Kent. *b* Sherborne Lodge, Dorset. *c* Bramshill, Hants.
d Dorfold House, Cheshire. *e* Wollaton House, Notts.

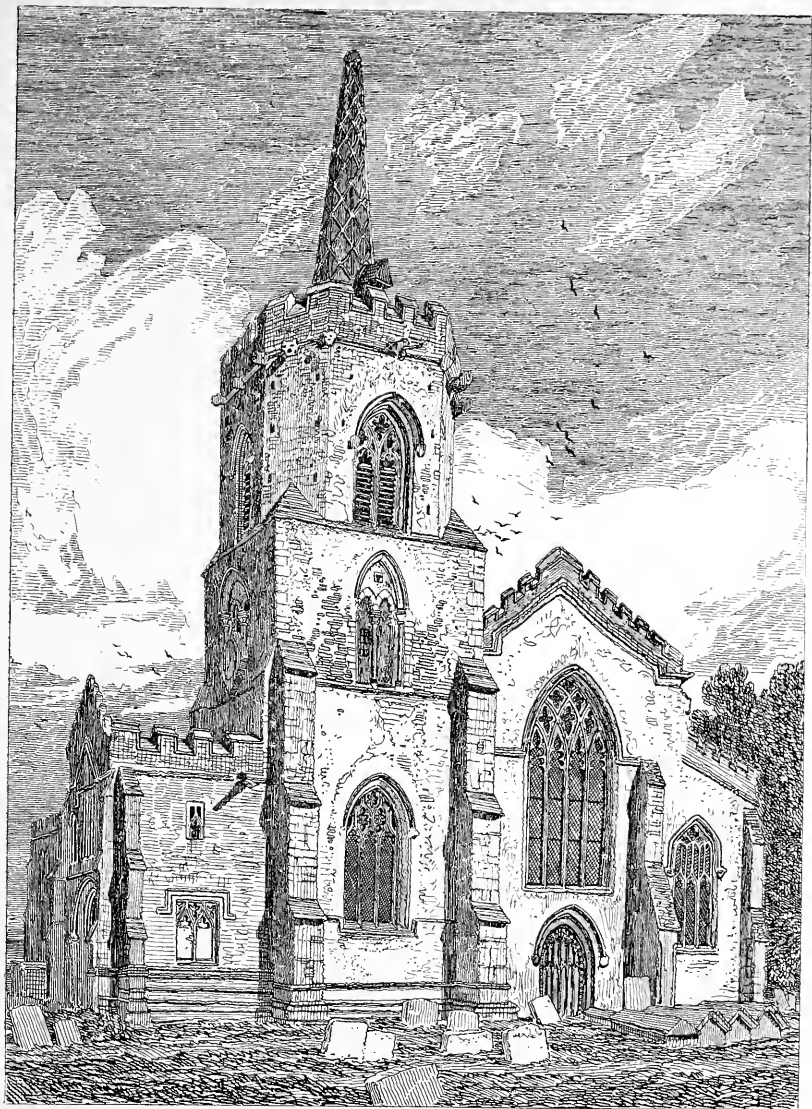


FIG. 128a.—NORFOLK. UPWELL CHURCH. (Cotman.)



[Photograph, Architectural Press.

FIG. 128*b*.—AN EARLY DESIGN FOR ST PAUL'S ILLUSTRATING WREN'S ART OF GROUPING.
(From the model in St Paul's Cathedral.)



[Photograph, *Architectural Review*.]

128c.—ST ANNE ROYTON, LANCASHIRE, BY TEMPLE MOORE.

VII. 9. Theory and Elements of Architecture

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BARN ON THE COAST OF ARGYLLSHIRE.

[M. F.]

Chapter VIII

DOORS AND WINDOWS

1. *ORIGINAL MEANINGS*

IN the preceding chapters buildings have been viewed in their general aspect as enclosers of space. By means of wall and roof combined, man is able to mark off a fraction of the infinite space surrounding him, give it shape and character, and carry on within it his own life, or some special part of his own life, distinct from the universe outside. But since his own life is related to the universe outside he must frequently pass in and out by means of a door. Also since light and air are necessary to life inside as well as out there was another use for the opening distinct from man's exits and entrances; it was also necessary to his health as a window to admit the sun. This passage to and fro between an inner and an outer world, this intercourse between man and his environment necessary to his health is at the root of all ancient symbolism attached to door and window. An architect when he designs a door is dealing with fundamental things in human nature so taken for granted that they have now almost passed out of the consciousness of the designer. But this is sheer loss. These fundamental things and their building symbols have appealed in all ages to imaginative people and are at the root of speculative Masonry and other humanist "crafts" and religions;

but the architect should have a special sense and knowledge of them and should constantly restore and re-interpret them in modern design.

It follows, therefore, that the earliest opening was door and window combined—it served equally for the passage of men and for the entrance of light and air. When the sun was recognised as a source of light and life the window element in the opening—that which admitted the sun—increased in importance. The first rays of the sun dispelled night and fear. Thus a simple form of temple was a little house for a god or for an altar having an opening to catch the first rays of the rising sun. Sun-worship, or light-worship, the most fundamental of religions, naturally emphasised the eastern opening. One of the commonest Egyptian symbols is that of the winged disc of the sun upon the lintel of an eastern door (Fig. 75); from the same motive grew the huge eastern pylons or gates of the Egyptian temple. A whole system of ideas sprang naturally from the simple fact of the sun for ever rising again after apparent death and being welcomed by men through an eastern opening. The entrance of the sun at dawn into the rock-cut temple of Abu Simbel in Egypt has been described thus:—

“On certain mornings in the year, in the very heart of the mountains, as the sun comes up above the eastern hill-tops, one long level beam strikes through the doorway, pierces the inner darkness like an arrow, penetrates to the sanctuary and falls like fire from heaven upon the altar at the feet of the gods. No one who has watched for the coming of that shaft can doubt that it was a calculated effect and that the excavation was directed at one especial angle in order to produce it.” (1)

When the morning salutation or sacrifice became a ceremony a warning of the sun's rising may have become necessary to the priest. He soon discovered that certain stars by their positions gave notice of the dawn, and in the absence of clocks marked the passing of the night. Thus by watching stars and sun through an opening came about the computation of time, daily and yearly, with its immediate advantage to men in respect of their work. And it was soon found that the position of the building and the field of sky delimited by it was of vital importance. Hence the connection in all early civilisations of priest, architect, and astronomer, and especially was this the case in Egypt where the accurate computation of the year and the construction of the calendar was necessary for the succession of the crops (ii. 1). Hence is derived both the planning and orientation of sacred buildings and the mythology connected with them.¹ Man by the act of saluting his god discovered new and beneficial things. The temple embodied the idea of health and enjoyment (light), the idea of rescue from night

¹ See also *Appendix, Note 7.*

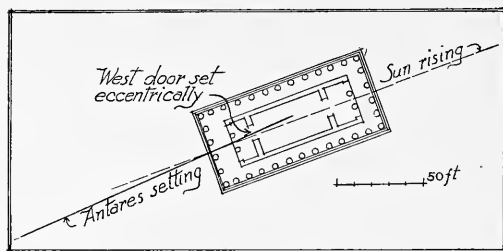
and fear (resurrection of the sun in the east), the idea of the unknowable (the stars moving across the opening).

There is strong evidence that when an Egyptian temple was built the direction of the axis was towards a point on the horizon (2) where some conspicuous star would rise or set,¹ and there are instances in Egyptian temples where doorways have been altered so as to keep in view a rising or setting star as it deviated from the first axis. According to Penrose Greek temples also were planned astronomically. There is no recorded Greek evidence of this, as for the Egyptian, but it is probable from the first principles we have been considering, that some such strong influence has had a direct bearing upon Greek temple design. In planning a temple with the rising or setting of a star sacred to a particular worship in view, both the axis of the temple and the angle subtended by the horizon would enter into the problem. Also the opening through which the sun was to shine upon the image of the god or upon the incense altar in front of it would require planning, and likewise the opening through which the "time star" was to be observed which was to herald the sun's rising. Thus the opening to the chief shrine of a Greek temple was not only door but sacred window also, and was generally, but not always, towards the east. The earlier and the later temple to Athena on the acropolis at Athens, according to Penrose, had the Pleiades for a time star—a constellation sacred to the goddess—and the divergence in axis of the two temples exactly corresponds to a shifting northwards of that constellation between the first and later foundation. But the time star was not observed only through the eastern door. At Aegina the door in the west wall of the cella has been placed a few feet north of the long axis "apparently for the object of enabling the setting of Antares to be observed from the adytum" (2) (Fig. 129). The more brilliant stars such as Sirius, Arcturus or Capella, "may be supposed to have been used at dead of night for producing a mysterious glow by reflection from polished surfaces according to the hint given by Herodotus² when speaking of a temple at Tyre" (2), and the lesser mysteries at Eleusis are considered to have occurred about the 19th of February in the lesser temple, "which exactly agrees with the

¹ A translation from an hieroglyphical relation of the rebuilding of a temple in the time of Seti I., about 1445 B.C., runs as follows:—"The living God . . . nourished by the sublime Goddess in the temple of the sovereign of the country, stretches the rope with joy. With his glance at *Ak* (the middle ?) of the Bull's Thigh constellation, he establishes the temple house of the mistress of Denderah, as took place before." At another place the King says:—"Looking to the sky at the course of the rising stars (and) recognising the *Ak* of the Bull's Thigh constellation, I establish the corners of the temple of her majesty." Norman Lockyer quoted by Penrose (2).

² Herodotus, Book II., par. 44.

appearance of Capella at midnight on the axis of this temple." (2) The sun was not always admitted by a door upon the long axis of the building. At Phigaleia near Bassae the temple of Apollo is orientated north and south, the main door and portico faces north (Fig. 138*b*), and a smaller opening in the eastern wall of the cella



[From Penrose.]

FIG. 129.—TEMPLE AT AEGINA SHOWING AXIS FOR THE SUN AND FOR THE TIME-STAR.

(Fig. 105) admitted morning light upon the statue of the god. This temple was "hypoethral," that is to say its main cell had an opening in the roof and it is probable that the field of sky given by the hypoethral opening in this and other temples was also used for the observation of the flight of birds and for divination by augurs.¹

The placing of a building with an opening on the primal axis of earth and sky thus directly influenced design both in plan and section. It caused the orientation of the pyramids, it caused the main entrance of the Parthenon to face away from the Propylaea so that religious processions had to go round the building; and it has also caused an eastern orientation in Christian churches. This is not surprising when we consider that Christianity also embodies the idea of resurrection or rising again and also the idea of the star in the east which heralded the birth of the Saviour. Many early Christian basilicas² had the apse to the west and the main door to the east, and this was common in east Christian countries until the fifth century. The bishop or presbyter then stood or sat in the apse behind the altar facing east towards the congregation. This orientation is found in the basilica at Silchester in England, thought to be Roman-Christian. Since the admission of light—that is the window element—gave the sacred function to the opening it is natural that eastern window should alternate with eastern door and come logically to supplant it. Thus Constantine's basilica of St Sophia at Constantinople had an eastern door and western apse. But Justinian's great church on the other hand has an apse with a central window on the axis pointing "somewhere between 30° and 35° south of east, where

¹ See meaning of words "temple" and "contemplate," note 2, p. 15.

² At Rome, St Peter's has apse to the west, also the Lateran Church. The first or Constantinian Church of St Paul's-outside-the-Walls had apse to the west, but the Church of Theodosius was reversed.

there is a considerable sea prospect and a low horizon. This direction either by accident or intention must agree very closely with sunrise at the winter solstice . . . Justinian's church was opened at Christmas."¹ Procopius, speaking of the apse, calls it "the *prosopon* of the church, that is to say, the part towards the rising sun, where the sacred mysteries are performed in honour of God."²

2. DOOR AND WINDOW COMBINED

In the common house (the home of a man as distinct from the temple or home of a god) the double use of door for light and access survives to-day in the "heck" or hatch door made with an upper half and a lower half, the upper able to open in order to light the interior while the lower remains shut. (3) Hatch doors are still found on the continent (Fig. 129*a*) and in charcoal burners' huts in England and in some of the Irish and Scotch cabins or "black houses" where the upper hatch is often the only window available. In France to-day the French window still retains the feeling of a door also, even when high up in the façade of a building. In the East there are, and always have been, many types of buildings in which the door is the only method of lighting the interior. The Classic house in its early form also illustrates this. Its arrangement consisted of a series of chambers one floor in height grouped round a court. The external wall surrounding the group had a few small apertures but the main lighting and ventilation was provided by the doors from each chamber into the court (Fig. 108).



[H. B.]

FIG. 129*a*.—HATCH DOOR AT RAGUSA.

3. DESIGN VALUES OF OPENINGS

Doors and windows being openings in a solid surface appear externally as dark objects on a light ground. Therefore they have a direct artistic value quite apart from their functions. They can emphasise the horizontal lines of a front as in a Florentine palace (Fig. 60), or the vertical lines as in La Motte

¹ Lethaby and Swainson's *The Church of Sancta Sophia*, p. 17.

² *Ibid.*, p. 24.

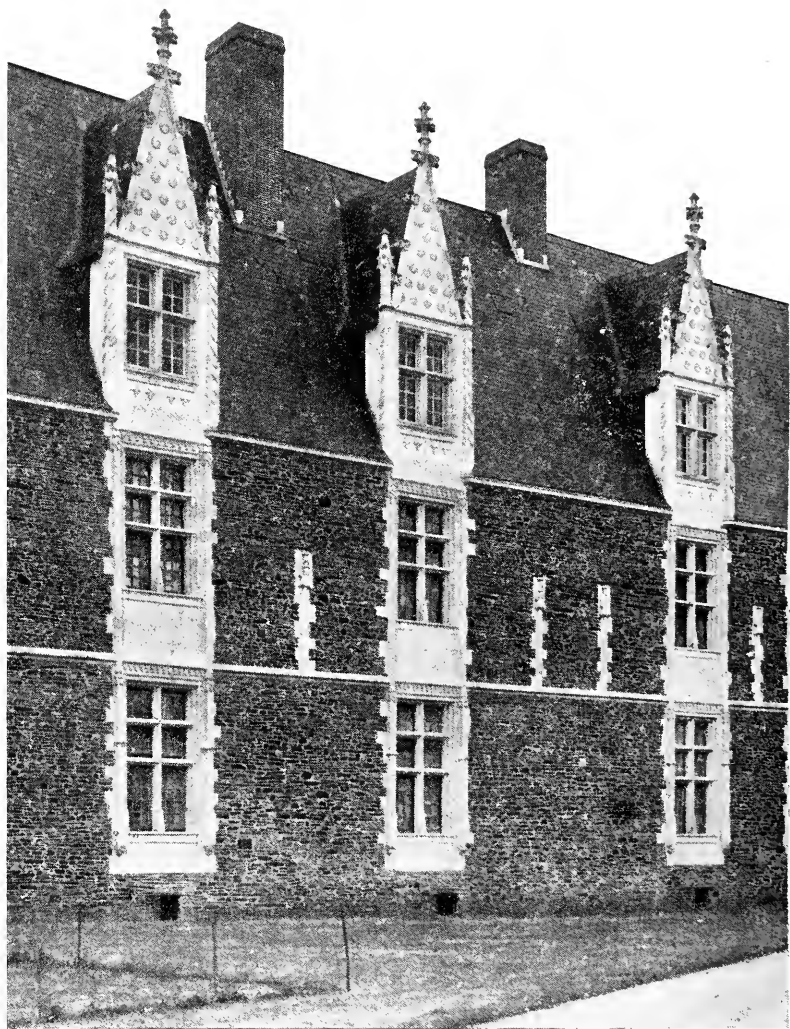


FIG. 129*b*.—LA MOTTE GLAIN.

Glain, a French chateau of the sixteenth century (Fig. 129*b*). In a quite plain design the openings can themselves form a pattern able to give a strong character to the building, as can be seen in our illustration of a Scottish barn on the Argyllshire coast in the headpiece to this chapter. Windows in rows can give the sense of number and monotony, or on the other hand a single large window can form a focus for the whole (ix. 8). Nor do the design values provided by windows concern only the single plane of the particular wall in which they are placed; they influence the cube of the whole building. Windows can be made to add to a solid effect by setting back the window or door frame and showing a deep "reveal" or opening. The depth of the reveal of the door or window is an important item in the external design; it can strengthen a wall or flatten a façade. The more massive a wall surface the deeper should be the reveals of the openings. A fault in the Pitti palace front as it now exists (Fig. 60) is that the reveals to the windows on the first and second floors are actually rather shallow, and as a result the enormous masonry blocks seem to have no depth, but to be a rugged skin. The depth of the reveal can cause window panes to reflect the sky or conversely can impart to a house a dark and introspective appearance. The noticeable difference in character between the appearance of an English and a Scottish town is partly due to the placing of the sash frame on the *outside* of the window opening in the English and on the *inside* in the Scottish.

The dramatic effect of a door can be considerable, and in this respect mere size is important. There is all the difference in the world between a large door and a little door. A large door at the head of a flight of steps—the permanent scene of the Greek stage—is alone setting enough for the Oedipus Rex. Compare and contrast the "little door" in "Alice in Wonderland."



[S. R. P.]

FIG. 129*c*.—VENICE. ST GIORGIO MAGGIORE.
An example of Loss of Scale.

VIII. 4. Theory and Elements of Architecture

A more detailed consideration of the design value of openings is given in ix. 8 and ix. 10.

4. PROPORTION OF DOORS¹

In designing a door the human figure was, and still is, the first unit of measurement. That is to say the obvious shape for a doorway is an upright oblong large enough to admit a man without stooping. The usual classical proportion for a door, though elaborately set out by Vitruvius (4), was approxi-



FIG. 130.—DOOR IN WEST FRONT OF WELLS CATHEDRAL.

[H. B.]

mately two squares high. But very large doors of this proportion will not look large unless some comparison with the human figure as a unit of height is maintained. This is illustrated in the west door to St Giorgio Maggiore in Venice (Fig. 129*c*). If the human figure in the photograph is covered over, the door appears inconsiderable in size. Also as the door, from its association with the height of the human figure, inevitably gives the scale to a building, a very large door of oblong proportion will not necessarily increase, but may diminish, the apparent size of a façade. Thus the small mouse-hole doors to the west front of Wells Cathedral (Fig. 130) give a greater scale to the building than does the Venetian door in St Giorgio (*see also* Fig. 141).

¹ See Appendix, Note 8.

Other proportions may be used instead of the oblong for definite purposes ; thus a large square door can express the passage of a ceremonial crowd or pageant, a low, wide-arched door gives a business or bee-hive air as of many persons on separate errands (Fig. 130a).

Now the width of a rectangular door is governed by the lintel (viii. 5) which was originally formed of one stone. The lintel suggests a limit of span and the more natural treatment of a wide opening is an arch. Therefore, when traditional materials are being used, *square-headed openings should generally be the narrower and arched openings the wider*. For instance a square-headed door does not look well with narrow arched windows. Where arched and rectangular openings are used together in a façade the point of the springing of the arches should give



FIG. 130a.—STOCKHOLM TOWN HALL.

[F. R. Y.]

a definite horizontal line, and this line, if possible should not be broken but form the upper or lower limit of the rectangular openings as is shown in our illustration of the ground floor of the palazzo Grimani, Venice (Fig. 131).

If the lintels rise above the spring of the arches the arched openings will

VIII. 4. Theory and Elements of Architecture

lose scale, as is the case with the doors in the west front of St Martin's in the Fields (Fig. 132), where the central arched doorway, though rising to a slightly greater height than the rectangular doorways on either hand, actually appears smaller.

Three large doorways of equal height placed together will diminish each other.

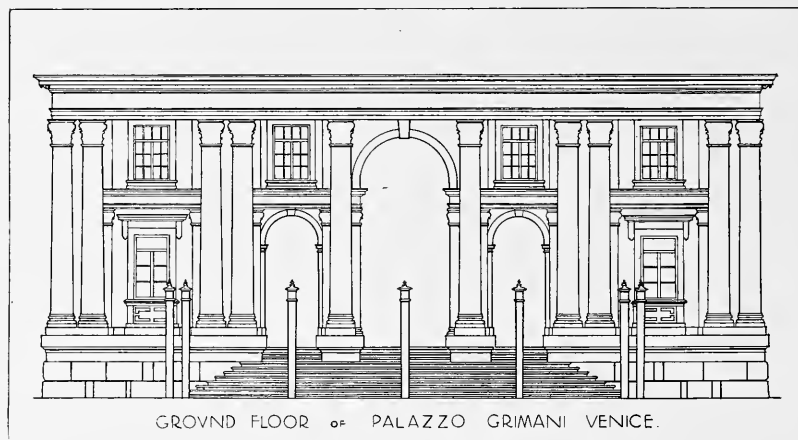


FIG. 131.—VENICE. PALAZZO GRIMANI. GROUND FLOOR.

The centre doorway should be slightly larger than the other two, then the three become at once a large trilogy as at St Pancras Church, London (Fig. 133).

The best method of preserving the scale of the human figure in large doors is to sub-divide their parts. The panels should appear to be many and small, and the mouldings upon the architrave, or margin, of the doorway should be related to the fingers of a man rather than of a colossus. Roman doors were frequently large but great care was taken to sub-divide them so that they bore a relation to the dimensions of the human figure. The huge Pantheon door (Fig. 134) is a lesson in scale. (5) Its opening is approximately 20 feet by 39 feet, and is first diminished by means of bronze pilasters supporting a lintel and fanlight of the same material above. Then the fanlight is divided by mullions, and the doorway is occupied by double doors in bronze each divided into five panels. But this is only the first series of sub-divisions. In order to reduce the unit

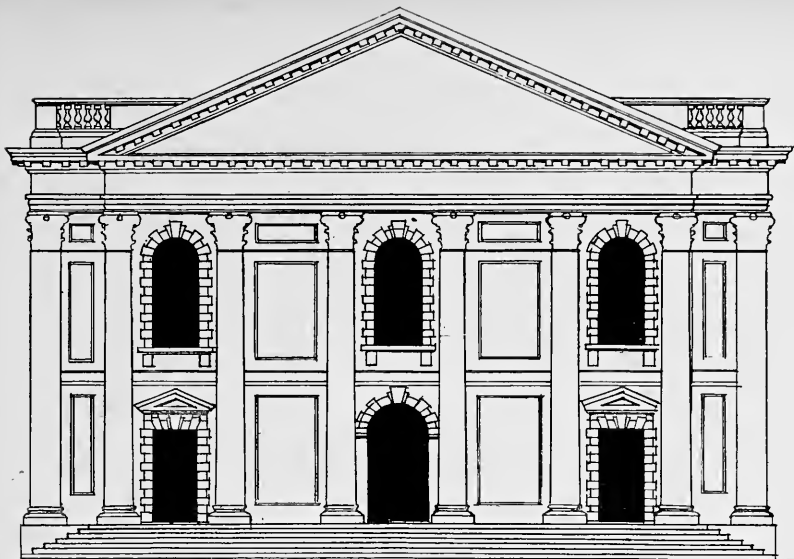


FIG. 132.—LONDON. ST MARTIN'S IN THE FIELDS. WEST DOORS.



FIG. 133.—LONDON. ST PANCRAS CHURCH. WEST DOORS.

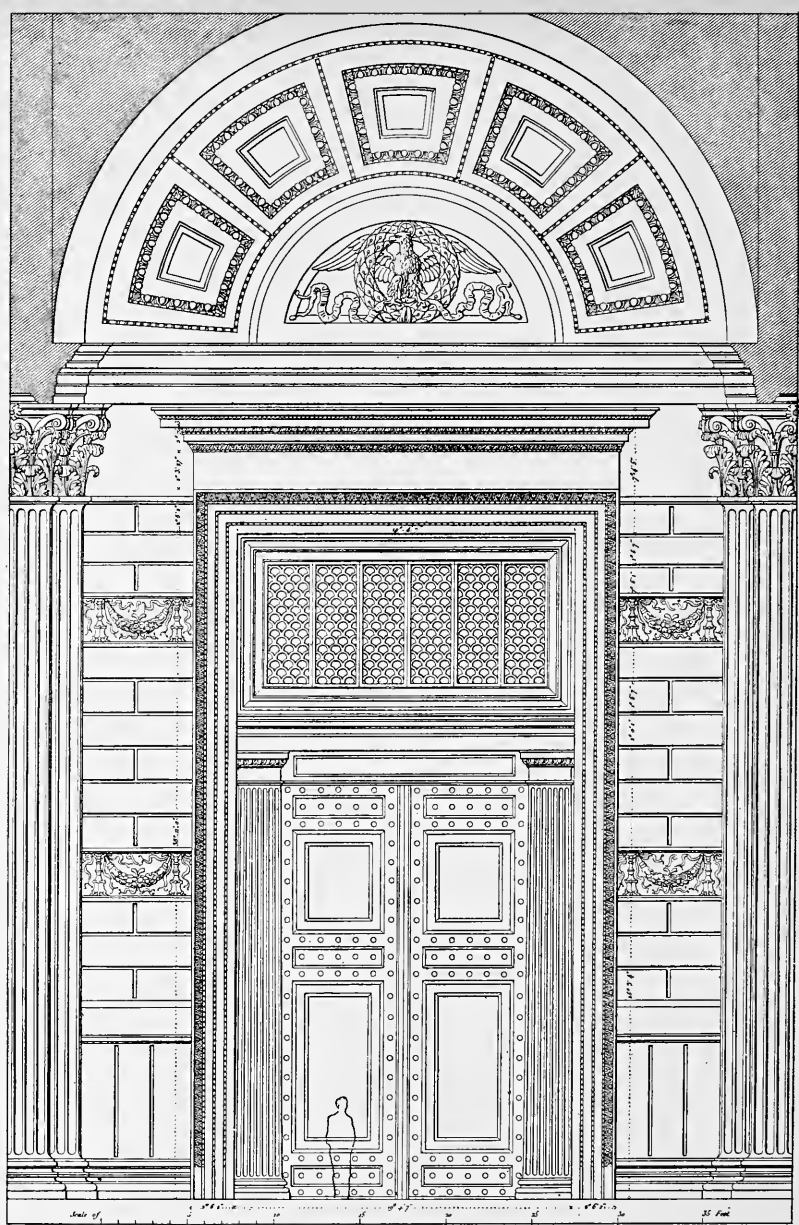


FIG. 134.—PANTHEON DOORWAY. (From Donaldson.)

of measurement still further the pilasters are divided into eight small flutes or channels, the fanlight is filled between the mullions with a bronze grille having a relatively small mesh, and the panels of the doors are dotted with nail-heads. The architrave outlining the opening, together with the cornice over the doorhead, is enriched with ornament having a small figure, and in addition the ornamental garlands on the wall touching the jambs are highly elaborated. Everything is done by multiplying parts to increase the scale of the whole.

In arched doorways the semi-circular opening over the door frame, known as the "fanlight," can also be sub-divided into a series of openings and can help to humanise the scale (ix. 4).

5. LINTEL AND SILL

A neat opening in a wall requires some experience in construction. The stones forming the sides or jambs have to be dressed, however roughly, and must carry the weight of the lintel. The lintel must be strong enough not to break by bending, and its bearings over the jambs must be of sufficient area not to crush under the load. Thus the lintel and its bearings are large and conspicuous and are the basis of all door and window forms. The span of the lintel depended, as we have seen, on the geology of the district (ii. 7). A large doorway very early in age and having vertical jambs is illustrated in the Alatri example (Fig. 135, 1). The next step was the inclining of jambs inward in their height

in order to reduce the span of the lintel and give it a larger bearing. This shape

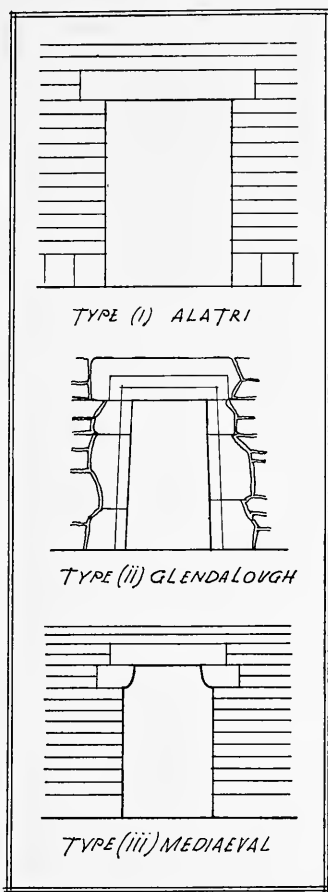


FIG. 135.—PRINCIPAL TYPES OF LINTEL DESIGN.

can be seen in very primitive masonry in a door in the Lady's Church, Glendalough, Ireland (*ii.*), and among the Greeks and Romans the sloping of jambs became a recognised form both for doors and windows. Another shape is given by projecting or corbelling out the course of stones immediately under the lintel and thus reducing the span. This type (*iii.*) is frequently seen in medieval buildings.

A danger where lintels are concerned is that of settlement. If there is

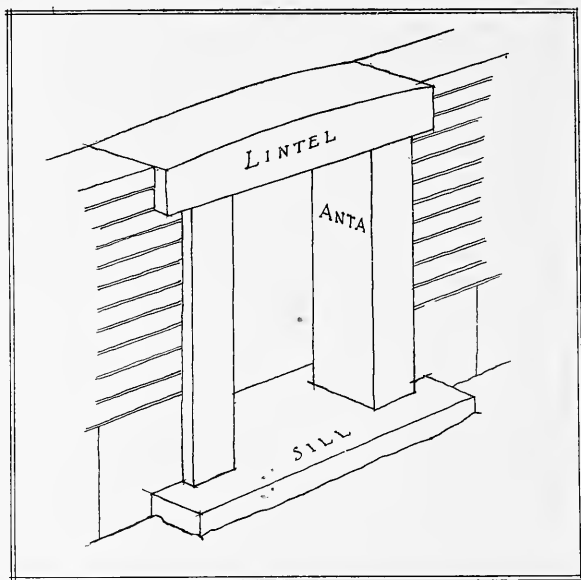


FIG. 135*a*.—ORIGIN OF DOOR MEMBERS.

unequal settlement between one jamb and another the lintel is liable to crack. Hence the importance of the sill-stone which should support the jambs and should be as large and strong as the lintel (Fig. 135*a*). This sill-stone is more noticeable to-day in windows but it is quite as important in doorways where it should support, and look as if it supported, the jambs.

Again, when the wall is in rubble masonry or mud brick the jambs of the opening have to retain the adjacent portions of wall as well as support the lintel. This is also shown in Fig. 135*a*. The jambs have thus to act as *antæ* and per-

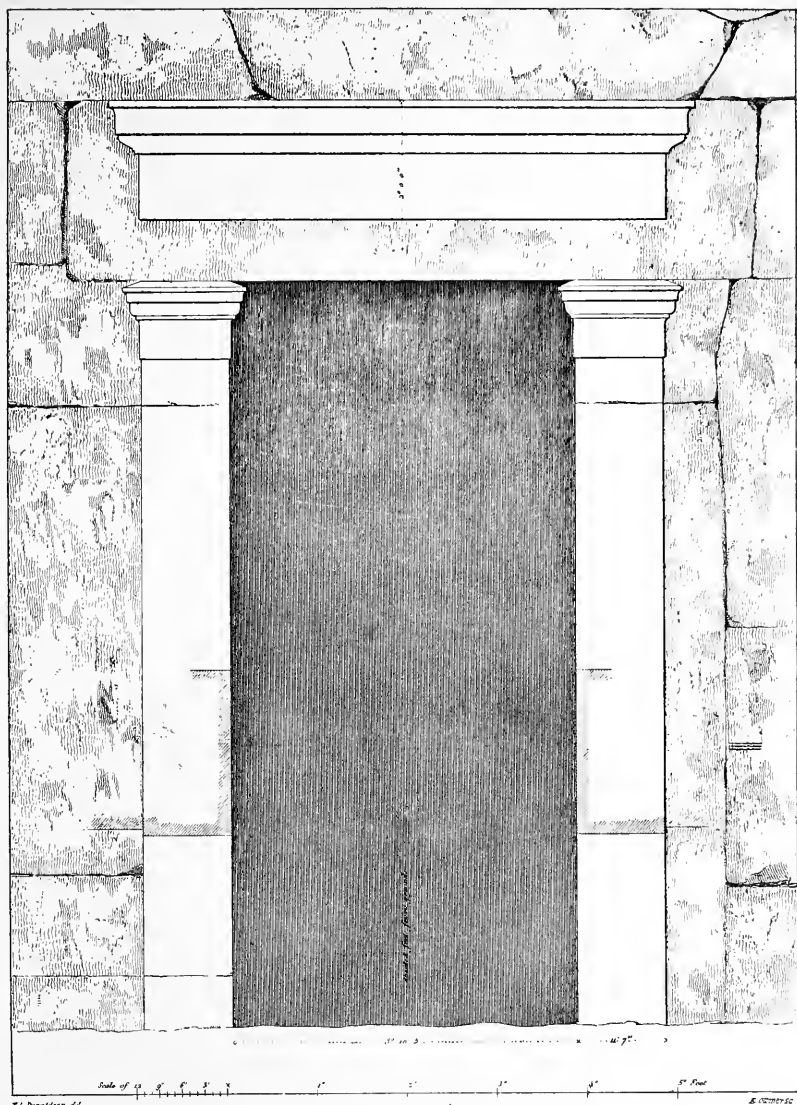


FIG. 135b.—CEPHALU, SICILY. ANTA DOOR. (From Donaldson.)

viii. 5. Theory and Elements of Architecture

form exactly the office of the antæ in the Mycenaean wall (p. 113). This has given rise to the stone-frame type of door (same figure), in which the sill is still

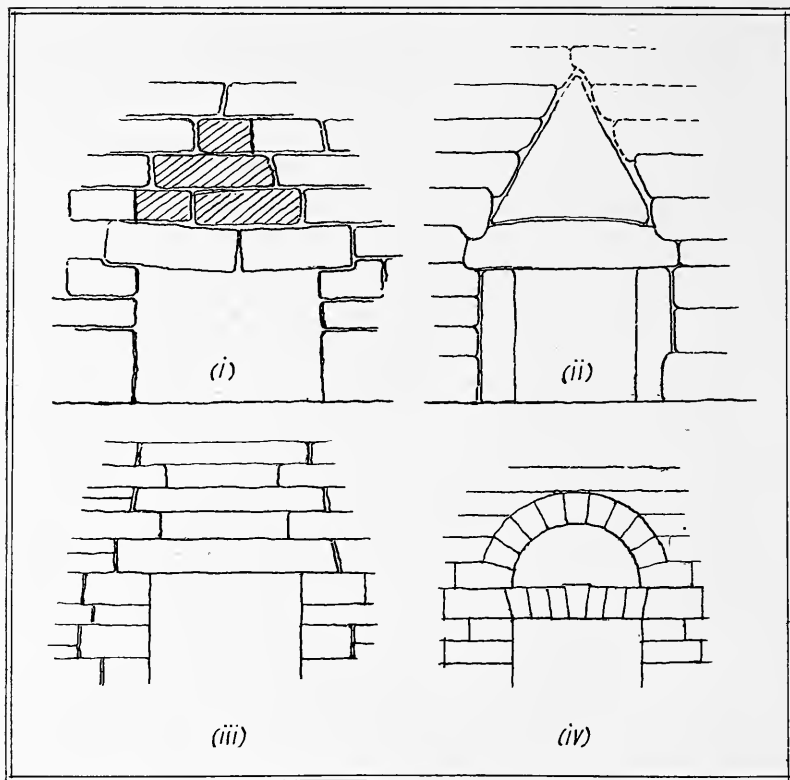


FIG. 135c.—METHODS OF RELIEVING A LINTEL.

important. In granite and grit-stone countries where long stones are to be had this construction is frequently to be seen to-day in its simplest forms. The rationale of the anta was refined and used by the Greeks (iv. II) for the stopping of walls; it was applied to windows by the Greeks in the Propylæa at Athens

(Fig. 16*c*) and to doors in Greece in all periods, and in Sicily as at Cephalu (Fig. 135*b*). The Cephalu door is a fine example of the expression of simple structure.

If the lintel of a door breaks, the wall above it will fall in up to an angle of from 45 to 60 degrees, above which the stone courses themselves bridge the opening if the adjacent portions of wall act as abutment (Fig. 135*c*, *i*). Thus the lintel is only carrying a triangular portion of wall immediately above it. This was soon recognised by early builders and we find a triangular opening



[H. B.]

FIG. 135*d*.—ROMAN LINTELS AND RELIEVING ARCHES IN THE FORUM OF AUGUSTUS, ROME.

left by the Myceneans above their conglomerate lintels within which was fitted a carved stone slab, as in the Lion Gate at Mycene (Fig. 135*c*, *ii*). This method of relieving the lintel was sound building and it is frequently used later by the Greeks in secular buildings as the walls of Messenia (headpiece to Chapter V.) and the theatre of Iassus (Fig. 59, *c*). A method less skilful is to place a narrower relieving lintel above the first (Fig. 135*c*, *iii*), as is seen in early buildings in Ireland.

The Romans, however, invented the most scientific method, namely, a “relieving arch,” turned in the thickness of the wall above the lintel in order to throw the weight upon the jambs as in the Tabularium, Rome (Fig. 135*c*, *iv*).

VIII. 5. Theory and Elements of Architecture

The relieving arch to be effective must be as thick as the wall resting upon the lintel.

This lintel plus relieving arch produced a characteristic design which is of great importance. The Romans rarely used a round-headed door without a lintel above or beneath.¹ They recognised the extra stress occurring in *voussoirs* and lintel by building these in travertine when they occur in a tufa wall (Fig. 135*d*).



[H. B.]

FIG. 135*e*.—KNOSSOS. PALACE OF MINOS.

Reconstitution by Sir Arthur Evans of timber-framed door and window.

But a lintel beneath a relieving arch has a higher factor of safety and can be more easily experimented with, and the Romans under these conditions evolved the “flat arch” or lintel composed of “voussoirs” or wedge-shaped stones. This was soon developed and varied. The doors and windows in the Forum of Augustus at Rome, illustrated in Fig. 135*d*, shows the inventiveness of Roman builders in the combination of voussoir and lintel. The space in the tympanum of the arch above the lintel, like the triangular space in the Mycenaean door, provided a place for a panel or for sculpture, and this had far-reaching effects in Romanesque and Gothic times (viii. 8).

¹ An exception is the large circular-headed entrance to the Forum of Augustus (Fig. 57). The general practice was either to place an arch beneath a lintel, as in the Colosseum (Fig. 53) and the Porta dei Borsari at Verona, or else above as a relieving arch, as just described. The combination of arch and lintel seems to have been an enduring tradition among the Romans.

We have now before us a few simple facts in construction. How have they been articulated in the general design of openings ?

Nothing is commoner to-day than to see whole streets of doors and windows elaborately detailed in which not one of these facts has been recognised. Yet all mouldings and "detail" should preserve a link with structural facts, should emphasise and refine them. The architrave mould outlines the opening and need be no more than a band. The common sense of this band is shown best by a simple, framed, timber construction such as the Minoan (Fig. 135*e*). An early moulding or emphasising of the shape of the opening, can be seen in Fig. 135 (*ii.*), in the marginal lines worked on the stones. But the chief fact of a door or window is the lintel which in a masonry technique should appear obviously strong and appear also to have sufficient bearing. Hence any defining line or moulding should return round the ends of the lintel and give a slightly wider



FIG. 135*f*.—CHIUSI. CASUCCINI TOMB. PAINTED LINTELS.

band to lintel than to architrave. When Etruscan builders cut a door between two excavated tombs they reproduced with a brush upon the rock the lines of a masonry lintel and jambs (Fig. 135*f*) such as they were accustomed to build above ground. These simple elements should not be lost sight of in the richest

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door or window. The return of the mould should follow the bed of the lintel

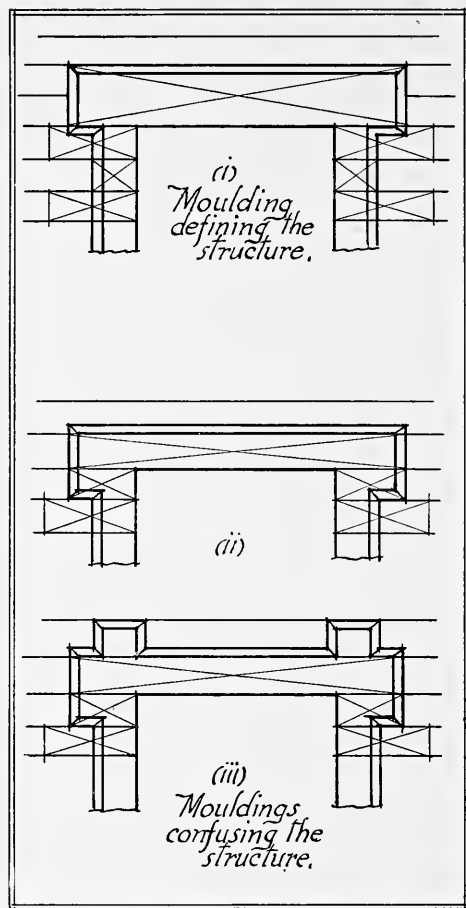


FIG. 135g.—LINTEL DESIGN. MOULDINGS AND STRUCTURE.

and therefore the moulds of doors and windows should always be designed in connection with the stone jointing (Fig. 135g, i). If the return of the mould includes also portions of jamb as in (ii), the mould is not outlining anything and is therefore meaningless; it is also meaningless when fancifully returned round non-existent ends as in (iii).

External doors require also a hood or cornice to prevent penetration of rain (ix. 9). This hood should surmount the lintel and project sufficiently to protect the joints below it. A fine example of a door depending only upon these elements, namely, lintel jambs and hood, for its shape can be seen also at Cephalu (Fig. 136, ii). It is possible to emphasise the lintel by ornament, as in the doorway at Corneto (Fig. 136, i). In the two window shapes in the Temple of Vesta at Tivoli, the sill, as well as the lintel, is articulated in the design in a perfectly satisfactory manner (Fig. 137).

Often, to give greater dignity to a door, the cornice or hood is projected on each side of the lintel

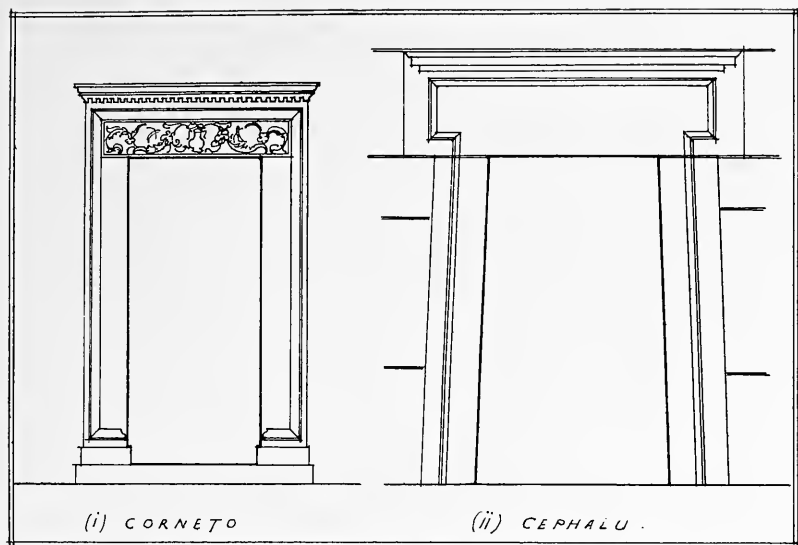


FIG. 136.—EXAMPLES OF LINTEL DESIGN FROM THE STRUCTURE.

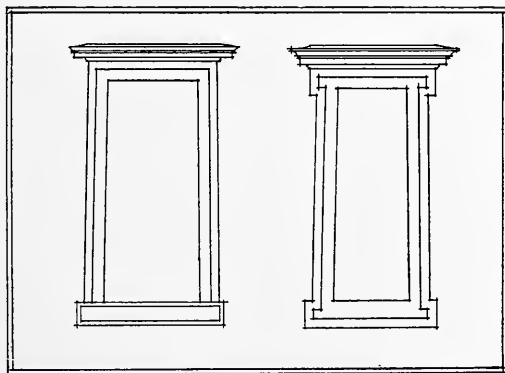


FIG. 137.—TIVOLI. WINDOWS FROM THE TEMPLE OF VESTA.
EXAMPLES OF SILL DESIGN FROM THE STRUCTURE.

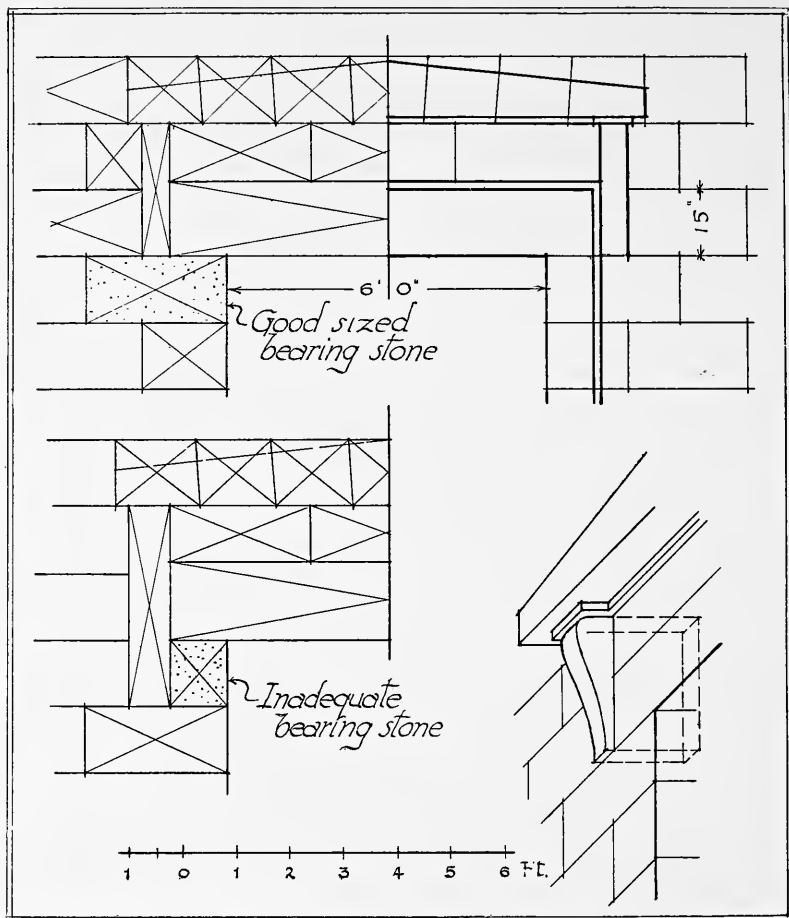


FIG. 137a.—EXAMPLES OF BRACKETS AND LINTEL DESIGNED FROM STRUCTURE.

and then requires to be supported on brackets or "consols" (Fig. 137a). These brackets should be tailed into the wall to a depth equal to their projec-

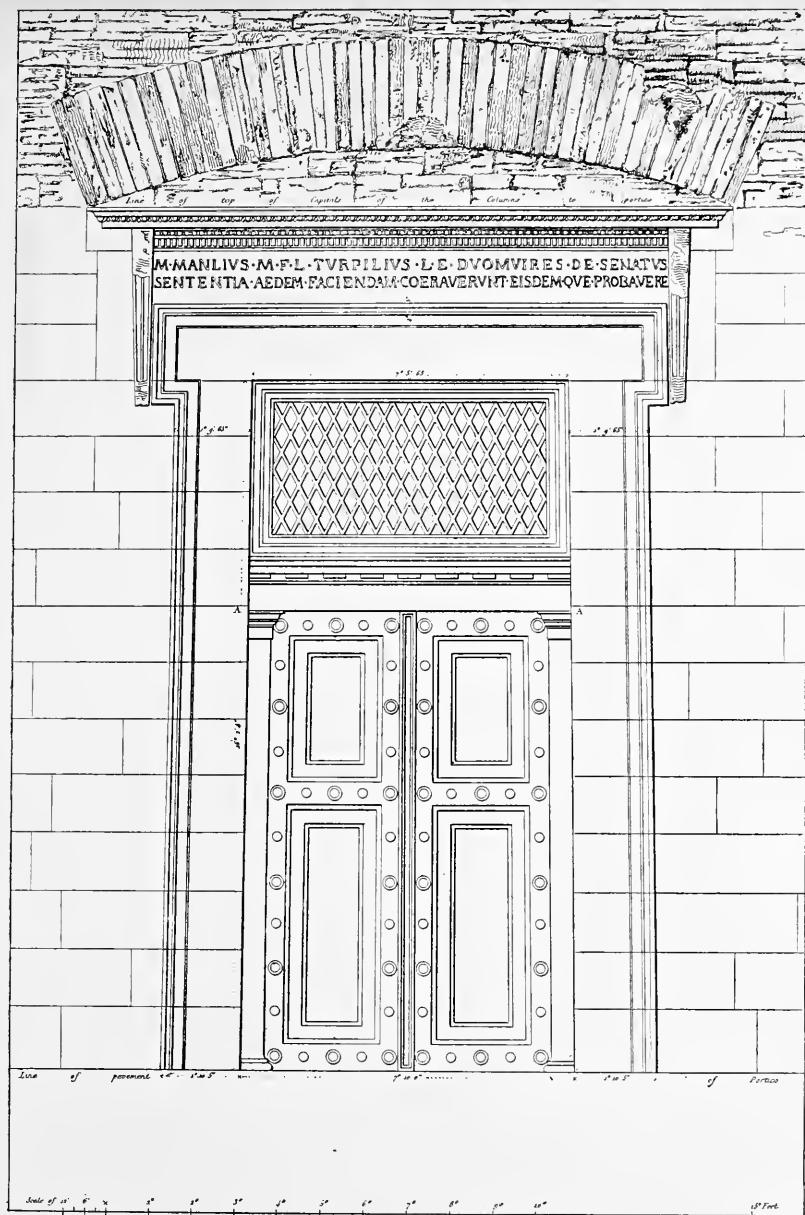


FIG. 138.—CORI. DOOR TO THE TEMPLE OF HERCULES. (From Donaldson.)

tion but they should not descend lower down than the bed of the lintel, otherwise they will cut into the course supporting the lintel and diminish its strength. (Compare (i.) and (ii.) in Fig. 137*a*.) This is the meaning of Vitruvius' rule:—"The brackets (*ancones*) which are carved on the right and left reach to the lower edge of the architrave exclusive of the leaf." (4) The reason of this is that the leaf can be carved upon the stones supporting the lintel without diminishing their strength. In the Massimi Palace door (Fig. 142*a*) the brackets are correctly designed. In the temple of Hercules at Cori the bearing of the brackets is really on either side of the lintel, the lower volute projects from the wall and slightly descends. This fine door shows also the proper projection of lintel over jamb (Fig. 138).

The hood should be designed to throw off the water on each side of the doorway—for which purpose the upper part should be given at least a slight slope or weathering, as in Fig. 137*a*. Full pediments over doors or windows are unnecessary and are liable to compete with the main pediment of the roof or the bay. Where the door is within a portico, hoods are foolish. The Erechtheion door in the north porch has only a level cyma moulding over the lintel to act as a hood (Fig. 138*a*). The Greeks did not put pediments over doors and windows inside of buildings as do the moderns, who indeed carry the whole paraphernalia of weathering indoors and make external cornices and pediments of considerable projection in drawing-rooms to defend walls and carpet from imaginary rain.

6. CLASSIC DOORS AND INTERSPACES

The placing of doors in early buildings should be studied in relation to orientation, for the reasons already shown (viii. 1). The doors of Greek temples considered thus have a special interest. In form they were generally a tall oblong with slightly inclined jambs as in the Erechtheion door (Fig. 138*a*). A large part of the lighting of the interior was through the main door but the Greek door not only admitted light, it also served as a frame for the god. At the Parthenon the eastern door was large enough to have yielded a view of the statue of Athena to a large number of persons in and outside the portico.

The Temple of Apollo, at Bassae (Fig. 138*b*) is also an interesting example of the placing of openings in relation to orientation and of using the door as a frame. As we have seen (p. 272) a northern aspect was chosen for the main portico of this temple and a smaller opening on the flank (Fig. 105) admitted morning light



FIG. 138a.—ATHENS. ERECHTHEION—DOOR IN NORTH PORCH.

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upon the statue of the god, which faced east. The statue was placed so as to be seen by a crowd in the northern portico, remote and ingeniously framed in profile beyond the doors and interspaces of the cells of the temple. Two impor-

tant elements in interior design, namely, frame and interspace are here recognised. There is an intelligent relationship between the two, and lighting is of the essence of the design. In the Parthenon the eastern door opens upon a large interior space. This is always desirable. In many Classic revival churches in England this was not recognised; the placing of a tower behind the west portico, as at St Pancras, caused a narrow vestibule into which the huge western doors open in a meaningless manner. On the other hand the fine effect of the west door of St Paul's Cathedral and of many large medieval churches, when fully opened upon the nave on a ceremonial occasion is obvious.

The Romans in their great secular buildings developed the effect of a series of openings upon an axis. In the Roman Baths doors were used as large rectangular frames ranged between vast interspaces varying in character. Such a plan as that of the Baths of Caracalla (Fig. 138c) shows remarkable contrasts in the shapes of rooms and great skill in the placing of axial lines. These axial lines were emphasised by a series of single doors or were broken by means of twin

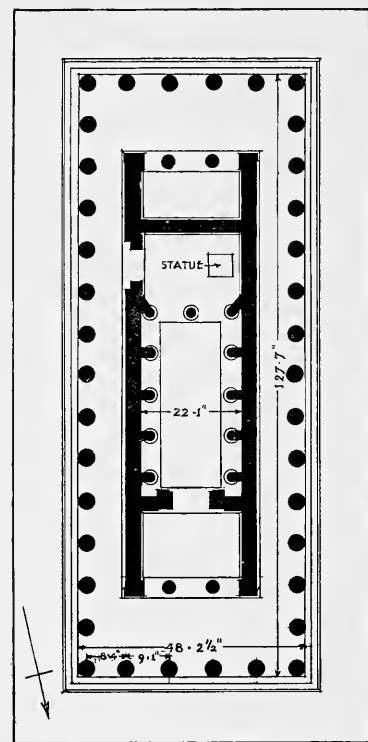


FIG. 138b.—PLAN OF TEMPLE OF APOLLO AT PHIGALEIA, NEAR BASSAE.

doors set on either side of an axis with a wall space between, or were diversified by a large distant opening containing a screen of columns. In the Baths of Caracalla to-day—even in their ruined state—it is impossible to walk through the large roofless enclosures and look along the vistas without experiencing the

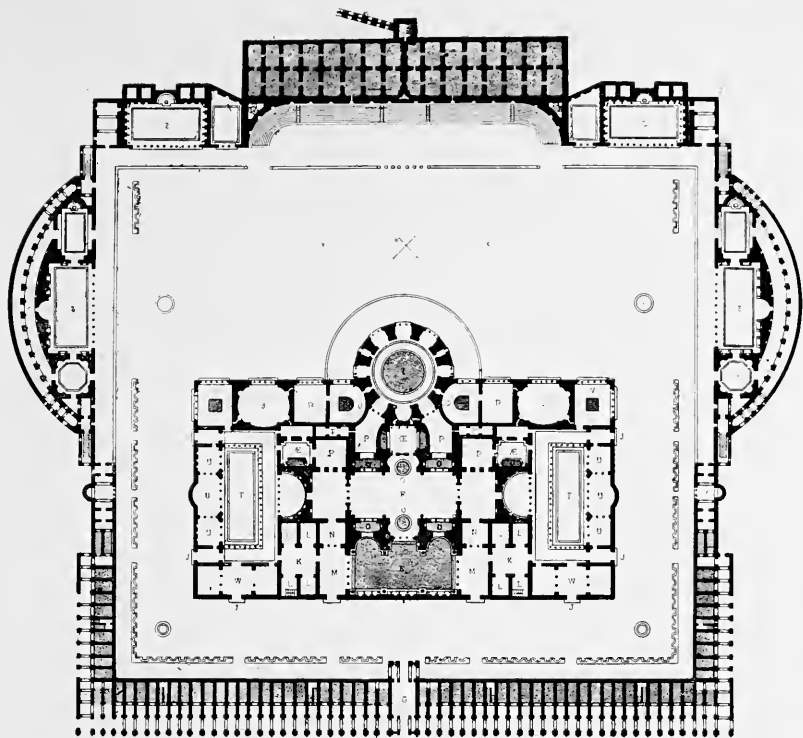


FIG. 138c.—ROME. PLAN OF THE BATHS OF CARACALLA.
(From Viollet-le-Duc.)

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grandeur of axial planning designed in relation to the openings and the interspaces.

7. THE HANGING OF DOORS

Doors were first hung by being pivoted, the pivots turning in holes sunk for the purpose in lintel and sill. Remains of Egyptian, Babylonian, and Etruscan doors of this kind still exist. The entrance to the Etruscan tomb at Chiusi, in the Casuccini Hill (Fig. 139) consists of folding doors, each door consisting of a single slab of travertine. They are to-day in the same state as when originally set up some hundreds of years before Christ, and still work well on their pivots. Each slab has a pivot worked out of the stone at top and bottom, and these pivots fit into sockets in threshold and lintel. The slabs must, in the first instance, have been set upright in position upon the threshold and the lintel then placed above them, socket fitting into pivot. Otherwise the doors could not have been inserted in the openings. The method of hanging doors by pivoting them between lintel-stone and sill-stone was used by the Romans in England; the pivot holes, and slides in the sill, can be seen at Housesteads in Northumberland. (7) The method continued through the Middle Ages.

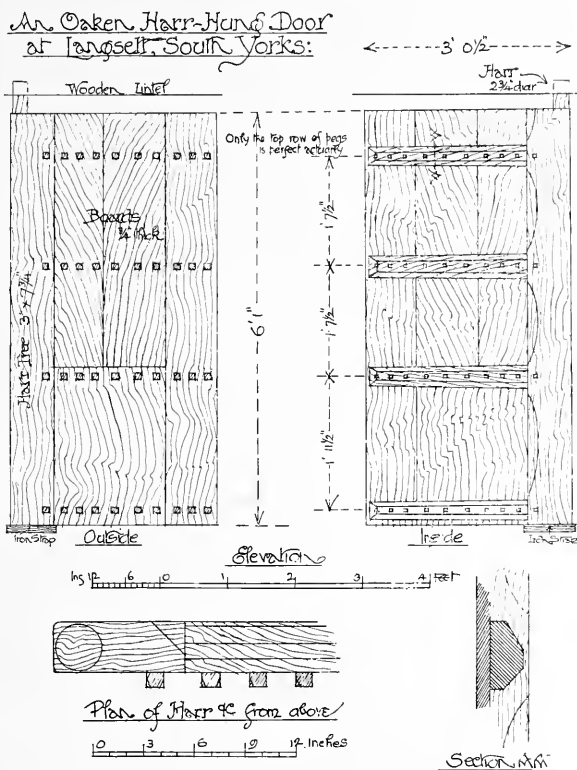


FIG. 139.—CHIUSI. CASUCCINI TOMB.
TRAVERTINE DOORS. (*Etruscan.*)

[H. B.]

Whether a door was hung or pivoted the constructional problem for the timber door was how to keep it rigid and prevent the free end from dropping. The commonest wood door really consists of two parts, the skeleton or frame and the boards or coverings. Reference to a field gate and the means of stiffening

it makes this clear—a gate consists of framing alone. The development from the earliest or batten door to the panelled door came about partly as the result of this



[By permission of the Cambridge University Press.

FIG. 140.—MEASURED DRAWING OF AN EARLY PIVOTED DOOR BY C. F. INNOCENT, SHOWING ALSO A STAGE IN THE DEVELOPMENT OF THE PANEL.

constructional problem. The process was as follows:—"The vertical board on the hanging side of the batten door was made thicker in order to strengthen it . . . and the battens are tenoned into it. Such an arrangement may be regarded

VIII. 8. Theory and Elements of Architecture

as the first step in the direction of the panel door, in which such a thicker hanging board is called a 'stile.' The further stages . . . may be traced. First came the thickening of the other outer board or stile in order to carry the door fastenings, and then came the placing of the battens at the upper and lower ends of the boards and the running of the fillets (or joint coverings) horizontally on a board or rail to form a decorative band. The last stages in the journey were the framing of the boards into the battens which then became true rails, followed by the recessing of the boards below the faces of the stiles and rails." (3)

Fig. 140 is a measured drawing by Innocent showing a fine example of a "harr hung" or pivot hung door. (3) The example illustrates the first step from the batten door to the panel door. The method of pivoting necessitates a thin slab or step placed under the "hanging board." The designing of heavy doors so that they shall remain rigid and able to turn easily is not an easy matter. As late as the nineteenth century specifications included the phrase "all doors shall be made to open and shut"; a phrase preserving a certain primitive wonder, a hint that there is something essentially marvellous about a good door.

8. MEDIEVAL DOORS

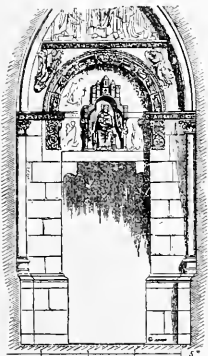
The Roman characteristic type of door, consisting of a lintel protected by a relieving arch (viii. 5) continued throughout the Middle Ages. Both lintel and relieving arch with or without corbels formed part of the design (Fig. 140a). The circular space or tympanum above the lintel provided in Romanesque times an excellent place for sculpture, as at Vezelay (same figure), just as the triangular space had done in the case of the Mycenaean door (Fig. 135c, ii). Many ingenious and beautiful designs for doors were made by the early medieval builder, using these elements only. In the figure we have shown two from Viollet-le-Duc.

Not until a considerable development had occurred in medieval technique did the circular-headed door appear side by side with the earlier kind. This was partly owing to the fact that wooden square-headed doors were more easily constructed than wooden circular-headed doors. The door was conspicuous and unavoidable, and its sculptures became an important item in the theological programme which every important church presented to the eye.¹ The west door was generally chosen for the representation of the Last Judgment, as at Vezelay, and for this purpose the lintel and tympanum panel were preserved. The medieval bracket projections can also be seen in the Vezelay door. Two

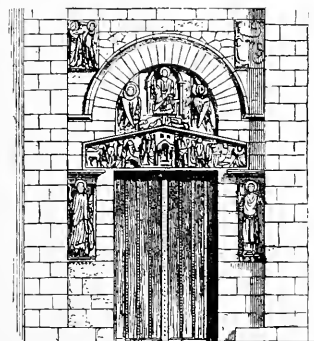
¹ See footnote 2, p. 239, in vii. 5.



Vezelay. Last Judgment sculptured upon the Door between Narthex and Nave.



Reims.

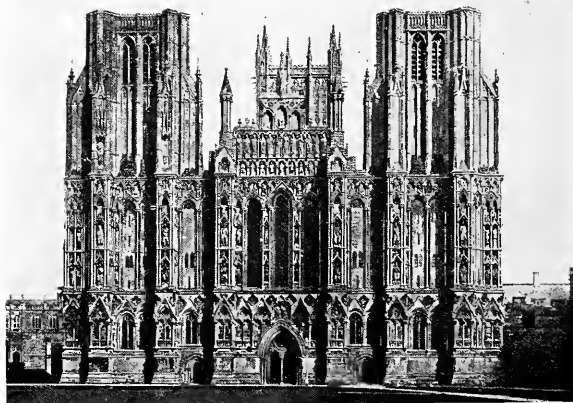


Clermont. Notre Dame du Port.

FIG. 140a.—MEDIEVAL DOORS EXPRESSING LINTEL AND RELIEVING ARCH.



Laon. West Front.



Wells. West Front.

FIG. 141.—COMPARISON OF FRENCH AND ENGLISH WESTERN DOORS.

openings were often included, giving a centre pier or *trumeau* supporting the lintel at its centre, and in Gothic times under a tall pointed arch the panel became of great size. The sculpture also encroached downward upon the lintel and upon the *trumeau*, and the whole became in many cases merely an expanse of didactic sculpture concealing the structure. The French Gothic builders carried forward and elaborated this tradition. Meanwhile the architrave or marginal band surrounding the Classic jambs and lintel had become transferred to the outline of the relieving arch and its imposts, and emphasised by considerable recessing. The recessed Romanesque arches called "orders" were at first covered with bold carved patterns, but were soon enlisted for symbolical sculpture, and by the thirteenth century the original simple marginal architrave (Fig. 136, *ii.*) had developed into a vast surround of saints, prophets, and angels such as adorn the western doors of the great French thirteenth-century cathedrals dedicated to Notre Dame. At Reims the tympana in the three western doors had grown so large that they formed windows, and sculptured gables were added above each (Fig. 152). At Chartres a large porch, in the nature of a kind of sculpture gallery, was added to the doors of the north transept.

In England, however, there was no parallel to this movement towards an extreme elaboration in sculpture, although Romanesque doors—such as at Rochester—are found with a Last Judgment in the tympanum panel. In England the sculpture is ranged instead upon the western fronts above the doors, and the doors are kept relatively small. Compare and contrast the fronts of Laon and Wells (Fig. 141). At Wells, indeed, the two smaller of the western doors are entirely within the large plinth or base of the building (Fig. 130). The English mouse-hole door is undoubtedly less spectacular than the French but generally gives a finer scale to the building (viii. 4). It is shown in its most masterly form at the foot of the towers of parish churches. Here it is intended to give scale



[H. C.]

FIG. 141*a*.—CHARTERHOUSE SCHOOL MEMORIAL CHAPEL. (G. Gilbert Scott.)

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to the tower and is generally designed in combination with a large window placed above it. Fine examples are: Evercreech, Louth, and Kettering. In these buildings English architecture achieves a refinement and a power scarcely surpassed, and in every case the door is relatively small. But, unlike the Classic revival church doors (already referred to, p. 294), these Gothic doors were generally designed to give upon a large space which opens into the nave through a tall arch. The traditional English combined door and window treatment is well seen in the fine modern Gothic building shown in Fig. 141*a*.

9. RENAISSANCE DOORS

The compound of cultures and race talents which from the architectural point of view caused the movement known as "Renaissance" was analysed in vii. 6. For reasons connected with the idea of a door (viii. 1) the progress of a cultural movement can be followed in door design. The beautiful naturalistic art of the later Middle Ages can be studied at its highest in a door such as the Portale del Palazzo d'Oria at Genoa (Fig. 112*c*). This door has the remains of the medieval corbel (*see* Fig. 135, *iii*) under the lintel, it has the Gothic cable mould, and on the lintel some fine figure-carving in which the most vivid movement is just sufficiently formalised for the purpose of architecture. Here the northern spirit, which we have specially considered under the head of roofs, seems after centuries to express itself superbly in a combination of logical structure and naturalistic figure sculpture.

In northern Italy, in Burgundy and Flanders, this art known also as early Renaissance was in full flower in the middle of the fifteenth century, and in Rome a French sculptor named Maestro Gian, according to Vasari, carved travertine with special skill.¹ But the movement is best known by its achievements in Florence.

The entrance to the Renaissance is through Ghiberti's bronze doors to the Baptistery in Florence designed as the result of a competition held in the year 1400 amongst Florentine craftsmen. The common stone of Florence we have already noticed (*iii*. 3). In the quarries at Fiesole and the neighbouring hills there had long been developing a type of stone-worker who was to rise to a place in the history of art beside the great Periclean masons and sculptors. The Florentine stone-workers, however, were only the leaders of an equally talented group of painters, metal workers, clay workers, all of whom mingled and exchanged

¹ Baldwin Brown's *Vasari: On Technique*, p. 52.



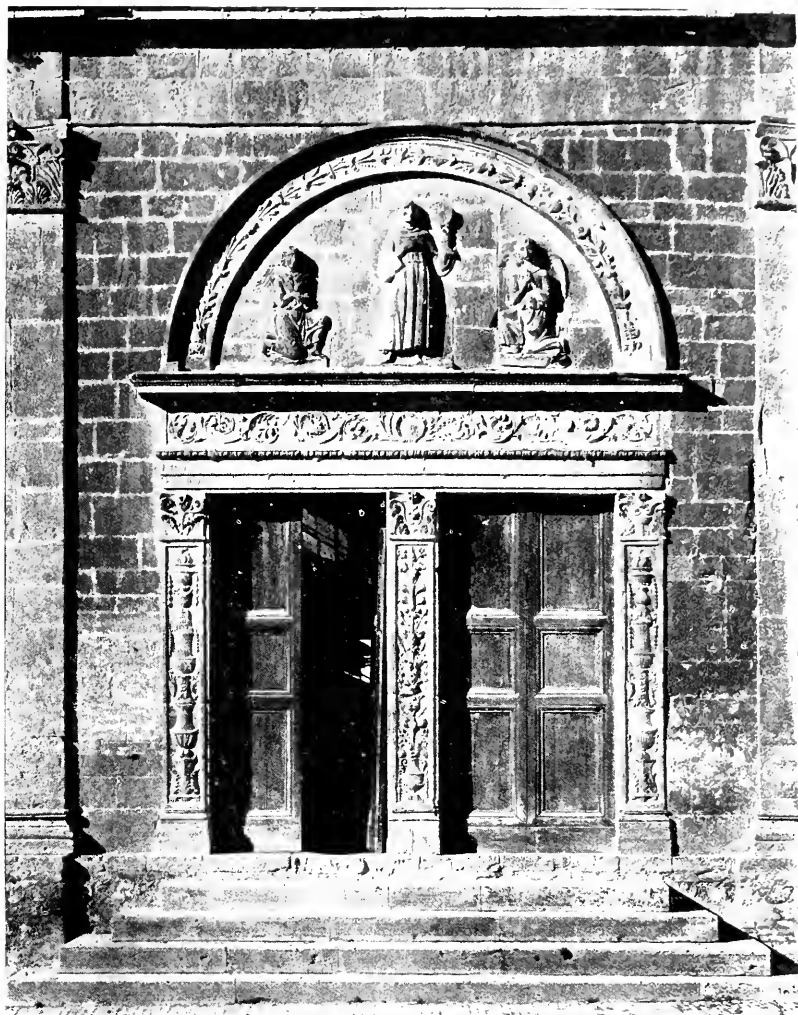
FIG. 141b.—FLORENCE. EAST DOOR OF THE BAPTISTERY.

ideas in the "bottega" or workshop and handled each other's materials. Hence a race of "architects" or master-craftsmen (in the original meaning of the term) were evolved who learned to control all elements with a peculiar knowledge, and who rose like the French church designers of the thirteenth century (vii. 5) to hold a unique position in their community and to consort on equal terms with princes and bishops. We have seen also that these master artists were employed by a race of patrons who chose to spend wealth in the search for beauty, and whose public buildings and private houses have remained the art galleries of succeeding generations (v. 6). The competition for the Baptistry doors was won by Ghiberti the metal worker. They are square headed and of a Classic proportion. The story-telling sculptural element is transferred from the margin and tympanum characteristic of the medieval door to the panels of the door itself—a treatment found in early Christian and Byzantine doors.¹ The panels to the north door of the Baptistry have a Gothic outline within a Classic rectangle. In the east door (Fig. 141*b*) the panels are square and larger. The architrave is a flat margin having a carved central band of flowers, leaves, and small birds. The size of the parts, both of the ornament and of the figures, is kept small and to the same scale so that the whole door appears of great size. The effect is both delicate and powerful.

The early Renaissance Italians had always before them the fine Romanesque and medieval doors such as we have shown in Fig. 140*a*. Now in these doors, as we have seen (viii. 8), the true lintel and relieving arch principles are carried out, and the Roman construction (viii. 5) is expressed and not disguised. In early Renaissance doors such as the door of the chapel of St Bernard at Assisi (Fig. 141*c*) the influence of the medieval door can be seen: the lintel is marked, the pediment is really a relieving arch and the detail is small in scale.

But there also survived the Hellenistic door of the Pantheon (Fig. 134). Brunelleschi, failing to win the competition for the Baptistry doors, travelled to Rome and while earning his living as a goldsmith made a careful study of the great Roman buildings. Brunelleschi's doors mingle two strains, as in the cloister of St Croce in Florence (Fig. 141*d*). He developed for himself the beautiful round-headed opening with continuous archivolt and delicately ornamented reveal, seen in the Pazzi chapel in Florence and in the cloister of the Badia at Fiesole. The large round-headed opening used between nave and aisle chapels is characteristic of Brunelleschi's churches and is seen at its finest in the Badia (Fig. 141*e*).

¹ As for instance the fifth-century door of the church of St Sabina at Rome.



[Anderson.

FIG. 141c.—ASSISI. DOOR OF THE CHAPEL OF ST BERNARD.



[Atinari.]

FIG. 141d.—FLORENCE. DOOR IN THE CLOISTER OF ST CROCE (Brunelleschi).

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A fine type of round-headed door with medieval voussoirs and with wide concave reveal was developed and used with great effect by the builders of the Florentine palaces (Fig. 142).

As the Renaissance developed the more formal Classic gained ground. Italian architects of genius, such as Peruzzi, were easily able to recreate a Hellenistic

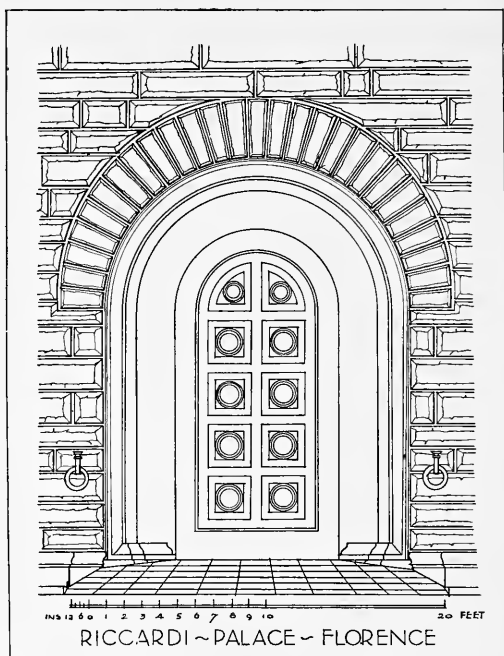


FIG. 142.—A LARGE ROUND-HEADED DOOR WITH CONCAVE REVEAL. (After Donaldson.)

door with the help of Vitruvius' instructions. The door of the Massimi Palace at Rome is an example (Fig. 142*a*) of Peruzzi's work.

The love of the Orders for their own sake led to the practice of ornamenting both doors and windows with columns. Columns used thus are liable to be themselves insignificant but to magnify the opening and lessen wall space (Fig. 159*d*). Only when they are re-conventionalised as antæ or pilasters on the structural

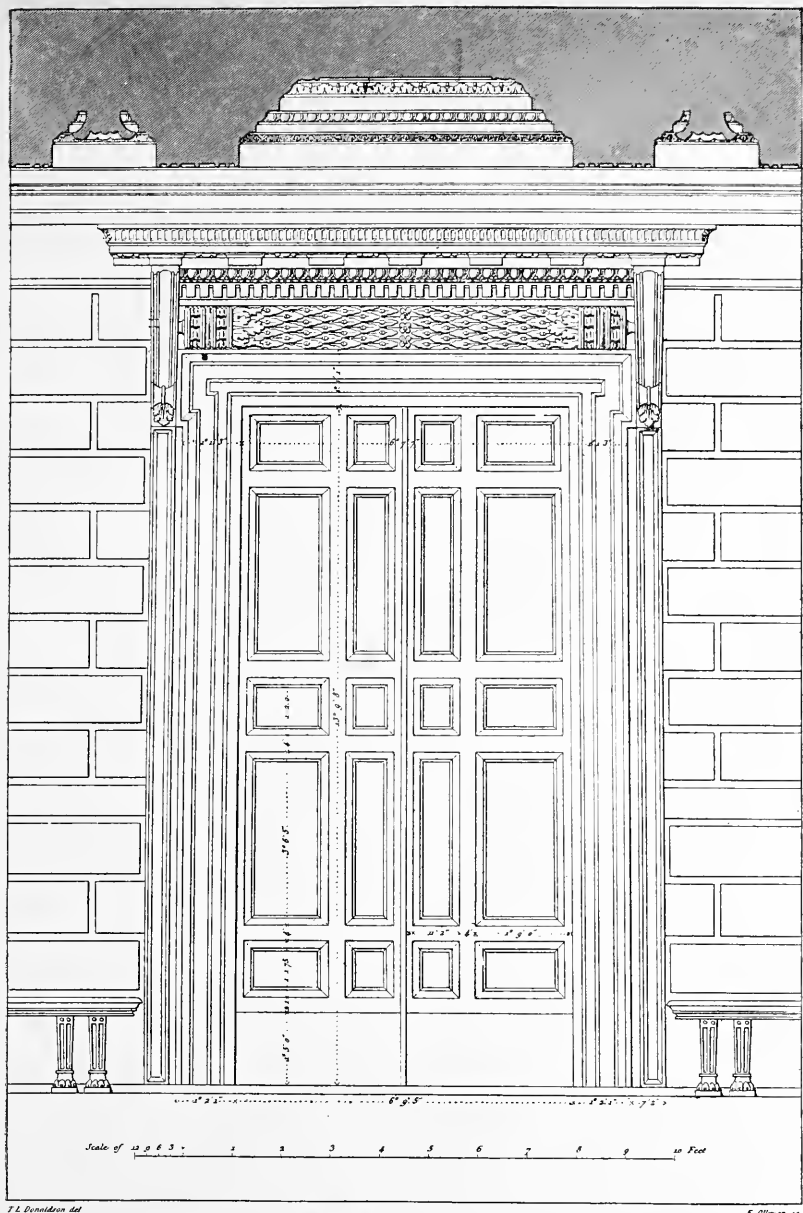


FIG. 142a. ROME. MASSIMI PALACE DOOR. (After Donaldson.)

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lines laid down in viii. 5 do the Orders look well when they are no more than door height.

This does not apply in the case of real porches and porticoes. In England,

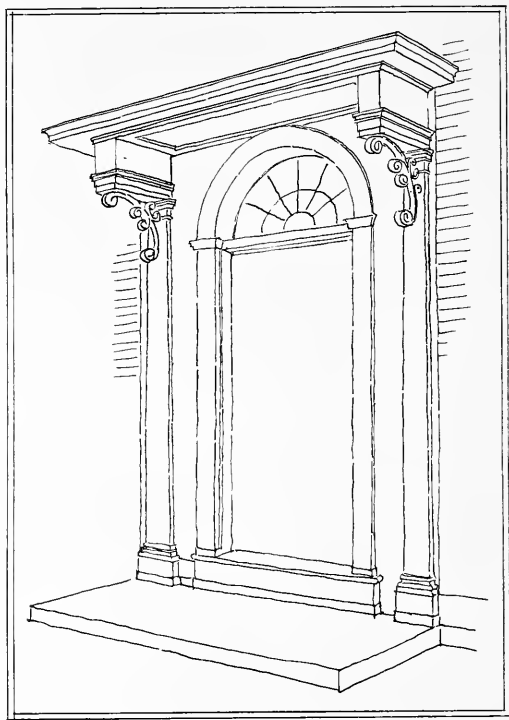
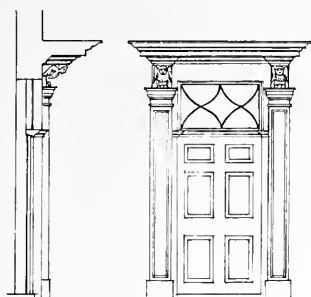


FIG. 142b.—DOOR AND HOOD. CHARLESTOWN, MASS.
(After W. Campbell.)

in the seventeenth and eighteenth centuries, Wren developed and enlarged the hood in a timber form upon brackets into a handsome and useful feature. This hood was much used for the doors of town houses too small for porticoes. The hood is a corona, or covering member—not a whole entablature—and should be treated as such; it is and should look like a board supported on



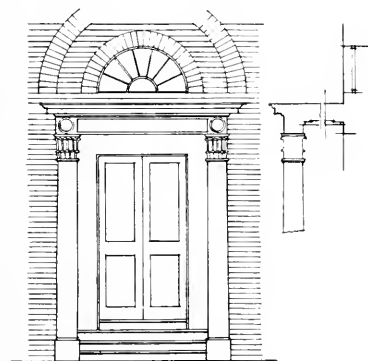
CRAIG'S COURT
CHARCH CROSS



36 BEDFORD SQUARE



KILDARE STREET DUBLIN



THE WICK-RICHMOND-SURREY

FIG. 142c.—EXAMPLES OF DOORS WITH FAN AND SIDE LIGHTS.

VIII. 10. Theory and Elements of Architecture

brackets or posts. The eighteenth-century American colonial builders in this as in other matters developed several rational and beautiful examples one of which is given in Fig. 142*b*. An objection to the hood when placed above a fanlight is that it darkens the hall, which on narrow sites often relies upon the fan opening for light. To overcome this difficulty the hood can be lowered and the fanlight placed over it as in the case of "The Wick," Richmond. The necessity to use the door as a window in city dwellings had led to several interesting types illustrated in Fig. 142*c*.

10. TWENTIETH-CENTURY DOORS

Exactly the same essential construction rules the general treatment of openings to-day as in the past. Steel or concrete lintels can take a wider span than masonry or flat arch but require a sufficient bearing area over the jambs and can be usefully relieved by an arch above. The bending and crushing strength of



FIG. 142*d*.—LONDON. WATERLOO ROAD FIRE STATION DOOR.

materials, protection from rain, and the height of a man, are still the ruling factors. Proportions may alter—they were sufficiently varied in the past—but the anatomy of structure remains the same. The persistence of antique common-sense principles (viii. 5) can be seen in the fine doors to the Waterloo Fire Station (Fig. 142*d*). The jambs and bearing stones are emphasised: the brackets fulfil Vitruvius' rule, and the cornice is necessary to protect the lintel from wet.

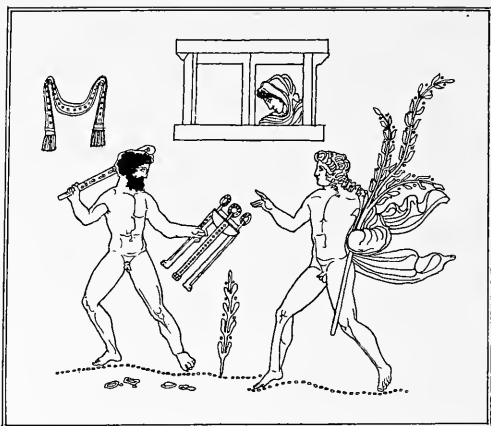
Certain new factors influence the design of entrances, as for instance the

fire regulations for safety exits or "crush doors." These always give a deep reveal on the outside for they must open outwards and swing back into recesses so as to give the maximum passage-way. In large buildings for public assembly a whole series of entrances are necessary. In this the best example is a Classic one, namely, the Colosseum at Rome where the arcade of the whole circumference admitted to the passage-ways. The architect of a modern exchange hall, or cinema, where the exits and entrances are continuously in use, would do well to consider the circumferential or semi-cumferential system of doorways.

The heating of buildings in cold climates has also led to the problem of the baffle or valve door intended to stop draughts. This is an important item. In a case like the British Museum a fine Ionic Greek door has been destroyed by a wood and glass lobby built within it in order to maintain the temperature in the vestibule. The trap lobby should be considered an essential part of the door design in large public buildings.

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FROM A CRATER IN THE NAPLES MUSEUM.

Chapter IX

DOORS AND WINDOWS—*Continued*

1. *INFLUENCE OF LIGHT IN THE DESIGN OF INTERIORS*

FROM inside a building the window opening has a converse effect to that upon the outside ; it appears as a bright space upon a dark ground. Light draws the eyes, and when people are congregated within doors for any meditative purpose the outline and brilliance of the window has considerable importance. The Christian church was a place of assembly as well as the home of the altar, crowds stood or sat with faces towards the eastern openings or moved in slow procession eastwards and westwards within the building. The inventiveness of builders where windows were concerned was therefore immediately noticed, so that it was natural they should develop in size, and become a source of colour display, and that their outlines, dwelt upon yearly by thousands of eyes, should become elaborated into tracery. The large English east-window became part of the English rectangular plan and the effects of light produced by it are unlike those produced by the continental apse. The large east-window has its disadvantages.

The narcotic effect of a large source of light in the eyes of persons seated cannot be ignored. In the nineteenth century it caused a movement in English church design towards the blind east end and the elaborate reredos, as in Butterfield's All Saints, Margaret Street, in London. In the design of modern places of assembly, a window behind the platform and facing the audience is to be avoided ;



(i) Florence. St Felice in Piazza.

[H. B.]



(ii) Spain. The Alhambra.

[R. C. B.]

FIG. 143.—EXAMPLES OF DESIGNING FOR GRADATIONS OF TONE UPON SOFFITS,

it draws the eyes and numbs the faculties, and is liable to throw the lecturer or speaker into silhouette.

The angle of light from windows upon internal planes and the gradations of shade produced should be used as data for interior design. In the past, skilful builders, either deliberately or instinctively have made use of data of this kind. In Fig. 143 (i), Florentine builders in the interesting little church of St Felice in Piazza have obviously used a western window to light some groined vaulting in a variety of tones and have pinched the groins in order to emphasise the effect. This pinching of groins is common in Italy. In (ii), the Moorish builders in the Alhambra have serrated the soffits of their arches in order to gather reflected



FIG. 144.—LIVERPOOL CATHEDRAL. THE CHOIR LOOKING EAST. (*G. Gilbert Scott.*) [Stear. Bde.]

light and get an increased brightness. In this beautiful interior planes, lines, colours, and patterns, have all been inter-related and made to contribute and contrast. The light admitted by windows into a room is only a fraction of the sky brightness and falls off rapidly with the distance from the window. "Actually the light in any ordinary room lit by windows on one side drops some 90 per cent. or more, between the window wall and the back wall." (1) This means that different planes, such as those given by wall and chimney breast, have upon a side-lit wall different tones deepening as they are distant from the window. Symmetry of tone is not possible on side walls but is possible on walls normal to the direction of light. On the same principle returns, splays, and recesses, should be considered in their relationship to the direction of light and distance from the window, and their gradations of tone (possibly emphasised by colour washes) should be used deliberately for an artistic purpose. Architects frequently use effects of line *only*, in interiors—namely the conventional mouldings which are the product of open air, not of interior conditions of lighting. The orthodox Italian scale of mouldings is inadequate and meaningless for the articulation of common interior conditions. Planes, colours, and intelligent patterns should be used by the architect as well as lines; and lines should also be considered in regard to actual light conditions. We shall see in the chapter on interior mouldings (in Part II.) that the Greek and the Gothic builders developed their interior mouldings logically, and that in consequence the interior mouldings differed from the exterior. In Liverpool Cathedral the choir vault, French in its construction, is deliberately lit from the east end only, thus giving marked contrasts on its planes (Fig. 144). The mouldings also show the influence of the light available and of the coefficient of reflection of red sandstone.

Some fine compositions in stage scenery have been made solely by means of light upon recessed planes; in this respect the work of Gordon Craig and Adolphe Appia should be studied. An architect has also these simple instruments at his disposal.

The Byzantine builders used the openings of galleries and arcades to give depth and variety to the interiors of their buildings and complement their flat wall treatment. This was partly the result of a concentration of their art upon the interior of a building—leaving the exterior plain—and upon interior conditions of light. Our illustration of the triforium of St Vitale at Ravenna (Fig. 144*a*) suggests, but only suggests, the kind of beauty of tone achieved by that means.

Other aspects of interior lighting are given in ii. 4 and ix. 12.

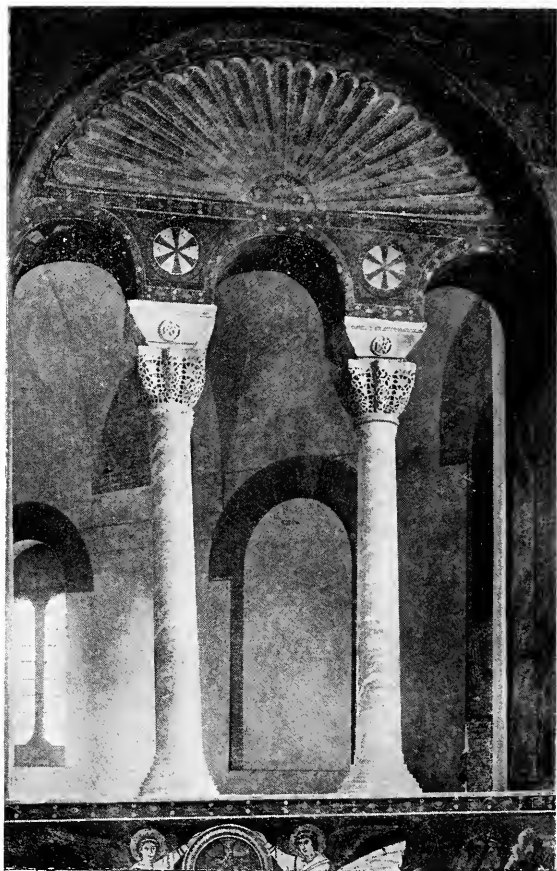


FIG. 144a.—RAVENNA. ST VITALE TRIFORIUM.

2. *EARLY WINDOWS*

The early development of upper stories in towns like Knossos in ancient Crete having admirable windows surprisingly modern in appearance (2) (Fig. 145), caused an immediate practical distinction between door and window. Another distinction, however, developed when glass came to be used and when a stage was reached in which men were sufficiently at leisure in the natural world to enjoy "the view." This contemplative use of the window meant a high stage of culture; it meant that man having originally built his house in order to shelter or separate himself from the universe, now opens it out to look again upon Nature from quite a new point of view, to find a harmony and a source of strength where originally there had been conflict and fear. In the history of architecture the emphasis of the window for this purpose is noticeable at several periods. The high culture of the educated classes in the Roman world is well illustrated in a single sentence from Pliny's letter to Gallus describing his Laurentine villa: "A little set back on the left is a roomy bedroom, then a smaller one, with one window to let in the dawn, another to hold the sunset; with a view too of the sea below—farther off, certainly, but safer."¹

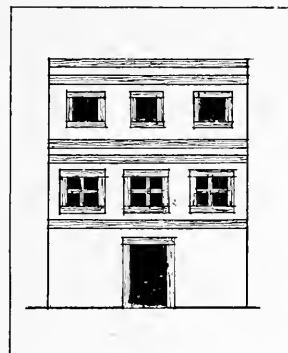


FIG. 145.—KNOSSOS. WINDOWS FROM THE FAÏENCE TILES. (After Evans.)

This sentence is interesting as also illustrating in the last two words some of that early apprehension—a last breath of primeval terror of the elements which we have forgotten to-day but from which we were first emancipated by the great Greeks and Romans.

In Egypt, as early as the old kingdom, houses had first and second floors with well-developed windows, which can be seen in tomb paintings and in the funerary models in the British Museum. Openings in the top floor were also formed by a row of little columns in the wall. A painting in a Theban tomb of the new empire (Fig. 146) represents a section through a house, and shows floors and floor joists, with lotus-capped stanchions to reduce the spans, and in addition

¹ Translation of Pliny's Letter to Gallus, by W. G. Newton, in "Imperial Building: What we may learn from Rome," *R.I.B.A. Journ.*, March 5th, 1921.

staircases, doors and windows (see also Fig. 1). In later Egyptian temples a

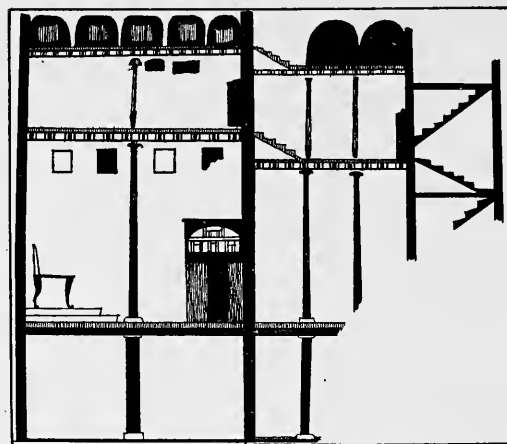


FIG. 146.—SECTION OF AN EGYPTIAN HOUSE FROM A THEBAN TOMB PAINTING. (*After Capart.*)

kind of window was sometimes formed by filling in the lower parts of a colonnade with a stone breastwork and leaving the upper part open, as in the temple of Hatshepsut, Medinet Abou and the temple of Horus at Edfou (Fig. 146a).

In Ionia where polygonal or rubble masonry was common the heavy wooden window frame had to act as retainer to the wall (viii. 5) and help to support the roof (Fig. 147). This type of window imitated or sculptured in stone survives in Ionian

tombs. In Scotland and Ireland where rubble walls are frequent the longer

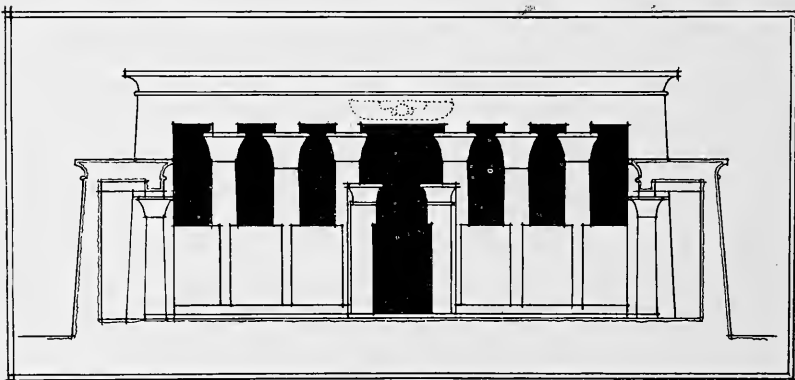


FIG. 146a. PRONAOS. TEMPLE OF EDFOU. WINDOWS FORMED BY BREASTINGS BETWEEN COLUMNS.

stones are used to retain the opening in the same manner and form a natural architrave.

In ancient Crete the timber window-opening required careful design in order to carry and retain the heavy walling in its neighbourhood. This led to strong mullions as can be seen in the reconstitutions by Sir Arthur Evans (Fig. 147a).

3. THE TWO TYPES OF WINDOW

The Classic window as seen at Paestum, the Erechtheion, the

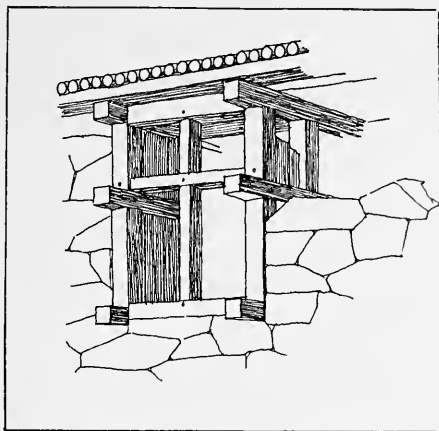


FIG. 147.—IONIAN WINDOW. (After Viollet-le-Duc.)



[H. B.]

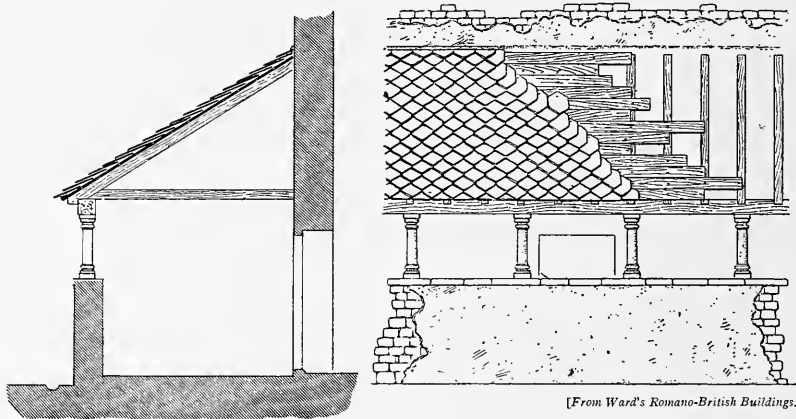
FIG. 147a.—KNOSSOS. MULLION WINDOWS RECONSTITUTED BY SIR ARTHUR EVANS.

temple of Vesta at Tivoli, and in the Roman flats at Ostia, is in shape the imitation of the Classic door with a proportion of two or more squares in height.¹ This proportion, handed on by the Italian Renaissance, is still followed. But it is by no means logical. A window might actually supply more light if it were two squares wide rather than two squares high. The restriction due to the lintel did not act in the same way as in the case of the door, because intermediate supports, such as the little columns in the top floor openings of Egyptian houses (*see* Figs. 1 and 146) or in the Hellenistic window shown in the headpiece to this chapter, could be inserted without destroying the chief function of the opening. The Romans in England modified their forms to suit

¹ *See Appendix, Note 8.*

our climate; by building a breasting wall round a peristyle court and supporting on it a pent roof resting on little columns or balusters widely spaced (Fig. 148) they produced openings horizontal in proportion as in the Spoonley Wood type of Roman house (3). So from the earliest times there have been two rectangular forms of window—the vertical or door-shaped, and the horizontal or mullioned.

The horizontal was developed to its fullest and finest by the English builders of the Tudor and Elizabethan periods. The Tudor window is the most adaptable of all windows. A small unit opening is used, in shape generally less than two squares high, and by placing these side by side, or one above the other, either vertical or horizontal windows can be formed in any position and of whatever size required. The vertical posts or “mullions” support the lintel or series



[From Ward's *Romano-British Buildings*.

FIG. 148.—MODIFIED PERISTYLE IN A ROMAN-BRITISH HOUSE. (*J. H. Middleton, adapted by J. Ward.*)

of lintels, and the mullions themselves are stiffened by horizontal members termed transoms. A large window so formed can be extended vertically through two floors and range with the smaller windows on each. The great adaptability secured in this way led to the elaborate fenestration of the large Elizabethan houses, of which Kirby Hall, Northamptonshire, or Astley Hall, Lancashire, are fine examples (Fig. 149).

The window consisting of a series of mullions has survived the Renaissance

period and survived the introduction of the sash, owing to its extreme suitability for domestic building in country districts. To-day it is a strong working tradition rivalling that of the Classic opening.

4. FANLIGHT AND GRILLE

We have seen that the large size of the Pantheon door (Fig. 134 and viii. 4) led naturally to the closing of its lower part by doors and the leaving open an



FIG. 149.—ASTLEY HALL, LANCASHIRE.

[Photograph by "Country Life."]

upper part or "fan" to give light. This principle of the fan was widely applied by the Romans; it also produced the characteristic window semi-circular in shape which has become a familiar form in architecture. This window can best be studied in the great Roman Baths: we give in Fig. 150 a restoration by Paulin of the Baths of Diocletian at Rome.¹ The vaults of these Baths have already

¹ Paulin, E., *Les Thermes de Dioclétien*, Rome, 1890.

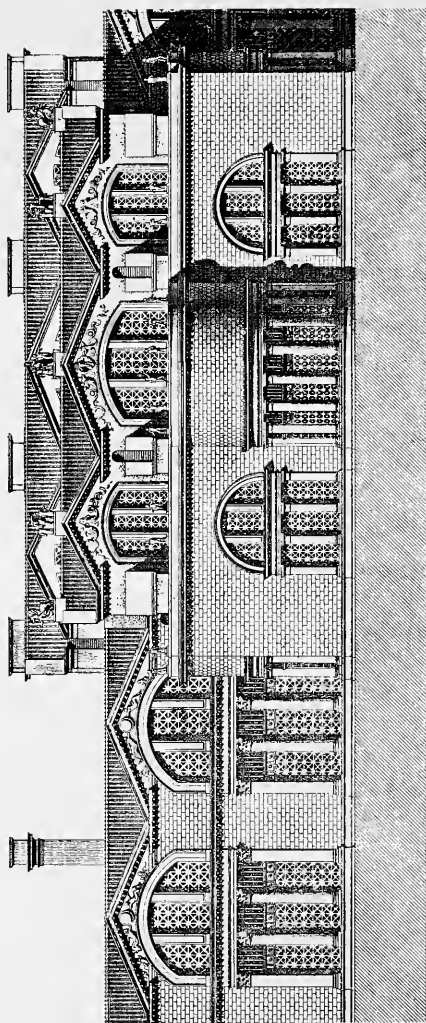


FIG. 130.—BATHS OF DIOCLETIAN, ROMAN SEMI-CIRCULAR WINDOWS. (*After Paulin.*)

been referred to (p. 70) as one of the great legacies left by the Romans ; they are equally important in the history of windows as of vaults. The windows were semi-circular because the vault was a barrel ; the tympana or semi-circular areas enclosed by the vault were left open for purposes of lighting, and were filled with grilles. But since the vaults were of huge span the openings were large and had to be sub-divided for the sake of the grilles. The sub-dividing was done by mullions ; the grilles were of metal or were formed of pierced slabs of marble or stone. Roman window design was thus a common-sense development of the Roman structural system and produced grand results.

If now we compare the north front of St Sophia at Constantinople (Fig. 150*a*) with the Baths of Diocletian (Fig. 150) we can see that the Byzantine builders were also working upon the Roman principle. The windows seen from outside are in groups and these groups correspond to the tympana of the vaults behind. The vaults show on the outside as relieving arches ; great interest is given to a plain elevation by articulating the structure in this way. The Byzantine window had the grille as an integral part just as the Roman had, but the use of marble slabs as filling between mullions was carried further, and monolithic shafts were sometimes used for the mullions themselves. Also rectangular openings of considerable size were often included beneath the semi-circle ; and in such cases (Fig. 150*b*) a transom or horizontal member marked the springing of the arch. In the rectangular part there was generally a low breastwork of marble ; shutters alternated with grilles. The shutters were either of wood or of thin marble slabs hinged ; and in the church of St Luke of Stiris at Phocis in Greece the marble breastwork also was so thin as to be translucent.¹ The grand window in the gallery of the north aisle of St Sophia, illustrated in Fig. 150*b*, shows clearly the nature of the design, namely, a filling between structure ; it has thus a direct bearing upon many modern problems.

The windows of early Christian basilicas for long preserved the Roman grille. They were often of large size. At St Pauls-outside-the-walls (before the fire of 1823) the clerestory windows were said to have been 14 feet 6 inches wide, and 29 feet high.² In old St Peter's the windows were on the same scale. But the light that came through them was limited because stone cut grilles of all shapes and sizes filled the openings. Examples at St Prassede and at St Silvestro in Rome are illustrated in Fig. 151. The narrow-pointed openings in the St Prassede example were rebated and glazed with sheets of mica, the latter kept

¹ Schultz and Barnsley, *Monastery of St Luke of Stiris*, 1901, p. 26.

² Ciampini, G., *Vetera Monumenta*, 1690, vol. i., p. 75.

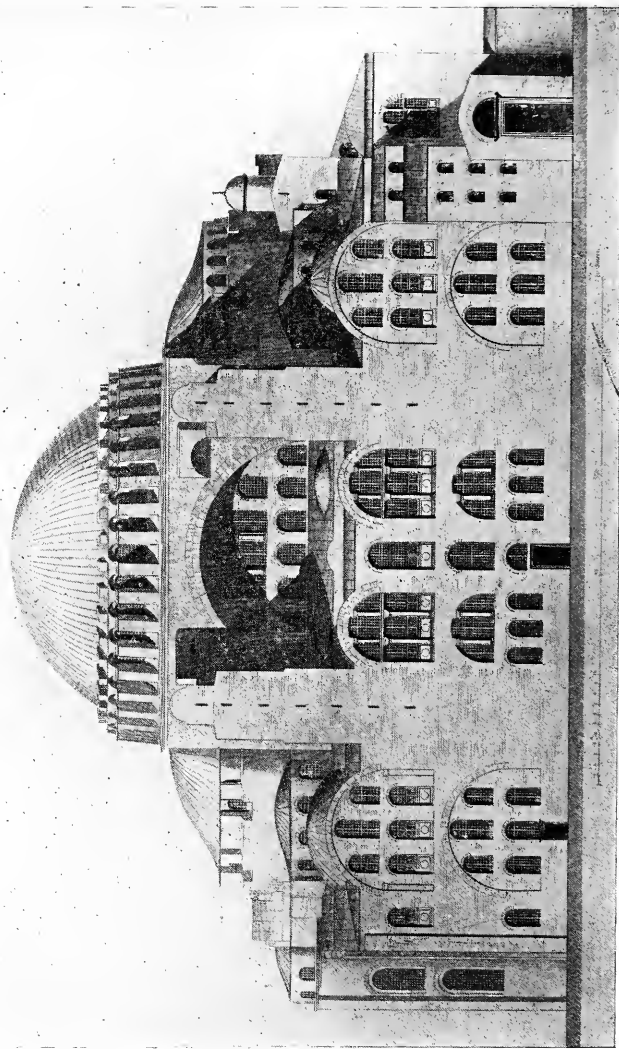


FIG. 150a.—CONSTANTINOPLE, ST SOPHIA, NORTH FRONT. (From Reynaud.)

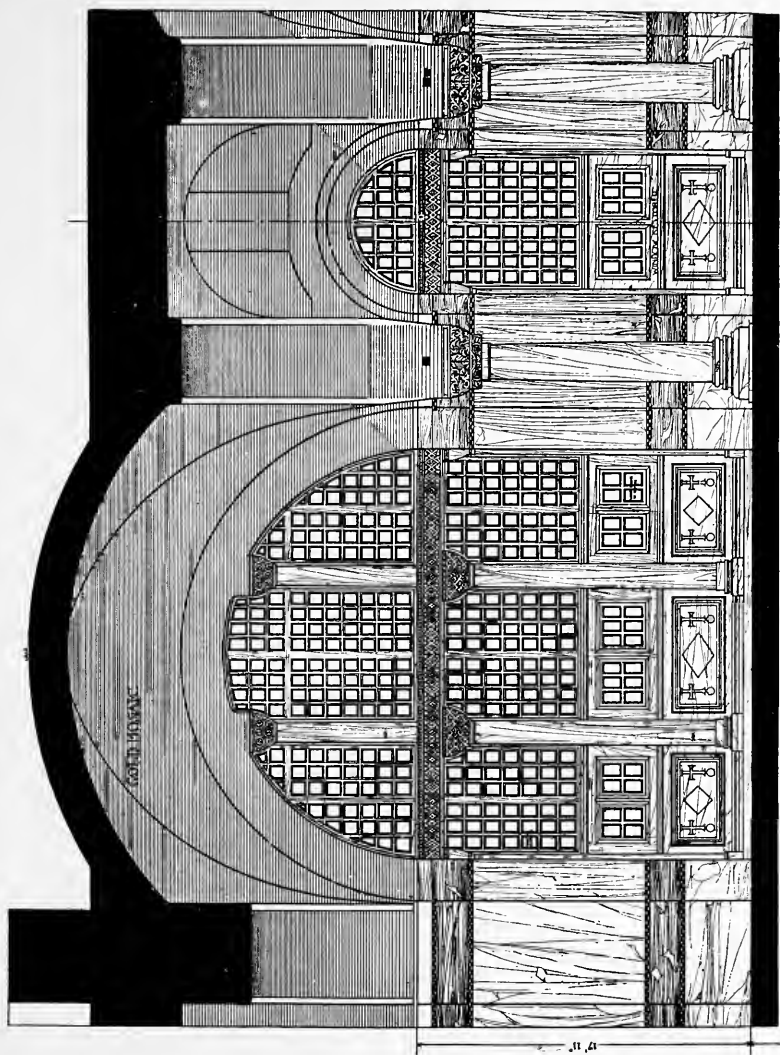
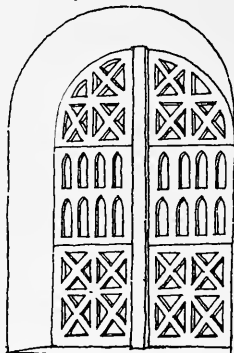
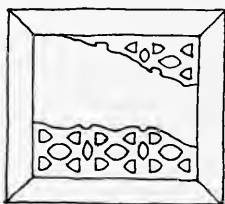


FIG. 156b.—CONSTANTINOPLE. ST SOPHIA, SECTION THROUGH NORTH GALLERY. (From a measured drawing by J. B. Fulton.)

(A.A.S.B., 1910.)



Window S. Prassede



Window S. Silvestro

FIG. 151.—EARLY CHRISTIAN GRILLES.
(From Nesbitt's Churches at Rome.)

in place by cement. (4) Glass was not a common commodity and it was necessary to have some light and yet be able to close part of the window against the weather. This caused the division, in many forms of early window, into a lower part furnished with shutters and an upper part left open or protected with an unglazed grille (*see ix. 5*).

The plate tracery of the Middle Ages was the outcome of a re-application of the principle of the classical grille to the head of the window-opening and of a new interest in geometrical shapes. In Italian Gothic where the window heads are frequently semi-circular the medieval tracery can be seen to bear a certain resemblance to the Roman grille as in the gallery of the Campo Santo at Pisa. The cloisters of medieval monasteries were frequently filled in with grilles and probably glazed. English reticulated tracery obviously resembles a grille. In France, in Reims Cathedral, there is a medieval example of a true fanlight (Fig. 152). The western doors are large in size and the tympanum above the lintel was filled in with glass. In Italy to-day, on the Lombard plain and the Campagna, the most ingenious grilles can be seen formed

out of bricks and roofing tiles of all shapes and sizes, and used in farm buildings and sheds (Fig. 152*a*). These tile grilles make excellent patterns; and fill in the tympana of arches and openings in the Classic manner. Probably the bronze grille of semi-circular mesh was imitated originally by the Etruscans from tiles used in this way. An unbroken tradition may survive here, as elsewhere in agricultural Italy, from the remotest Etruscan peasant sources.

5. EARLY GLAZING

The Romans, as we have seen, used glass or thin transparent sheets of stone or mica (ix. 4) in order to admit light and exclude rain and cold. Nero caused doorways of a hall in his palace to be filled in with alabaster.¹ Vasari says: "Some sorts of marble are found in Greece and in all parts of the East which are white and yellowish and very transparent. These were used by the ancients for baths and hot air chambers . . . and in our own days (1550) there are still to be seen in the tribune of San Miniato a Monte above the gates of Florence, some windows of this marble which admit light but not air."² The apse windows of San Miniato are still filled with slabs of antique *povonazzetto*, two inches thick. They do not admit much light.

— In the west gallery of St Sophia at Constantinople is the window known as the "Shining Window." It is thought that this was originally filled with white marble (iii. 4) from the Catacolon Quarries on the island of Proconnesus.

¹ Philo Judæus, *De Legatione*, 45. "He directs that the windows in a circle be taken up with stones as transparent as white crystal which will not hinder the light but keep off the wind and the heat of the sun."

² *Vasari : On Technique* (Baldwin Brown's edition, 1907, p. 43).



FIG. 152.—REIMS. FANLIGHT OVER WESTERN DOORS.

Glass was known and used by the Romans, and a pane of Roman glass roughly a foot square is in the Rochester Museum. "The window glass found on our Roman sites is rarely less than one-eighth of an inch in thickness and of a greenish blue tinge." (3) But in Roman, Byzantine, and medieval times glass used in windows was blown and not cast. The sides and ends of rectangular bottles were cut and used as panes. The ends of circular bottles and whole bottles were inserted in walls in patterns constituting grilles or rough windows. In Constantinople to-day this kind of glazing can still be seen.

In the Middle Ages glass was used, but used rarely for domestic purposes. The upper part of the window, as we have seen, was glazed and the lower rect-

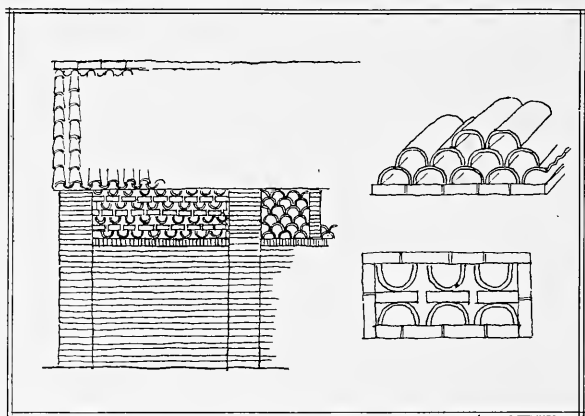


FIG. 152a.—BRICK AND TILE GRILLES IN ITALIAN FARM BUILDINGS.

angular part furnished with wooden shutters or doors. Sir Thomas More mentions in "Utopia" that the windows of the houses had glass or else "fine linen cloth dipped in oil or amber." By this means "more light cometh in and the wind is better kept out." . . . Harrison says :—"Of old times our country houses instead of glass did use much lattice and that made either of wicker or fine rifts of wood in checkerwise." Also—"some of the better sort, in and before the times of the Saxons, did make panels of horn instead of glass and fix them in wooden calmes."¹ . . .

¹ "Calme" or "came" is the term for the frame or glazing bars and is still used with reference to lead lights.

. . . “Heretofore also the houses of our princes and noblemen were often glazed with beryl (an example whereof is yet to be seen in Sudeley Castle) and in divers other places with fine crystal.” (5)

6. COMPARISON OF THE FRENCH AND ENGLISH WINECH

There are two methods of filling in an oblong window of Classic design, namely, the French method and the English method (Fig. 153). The French method is to place a transom above eye level and to fill the lower opening with

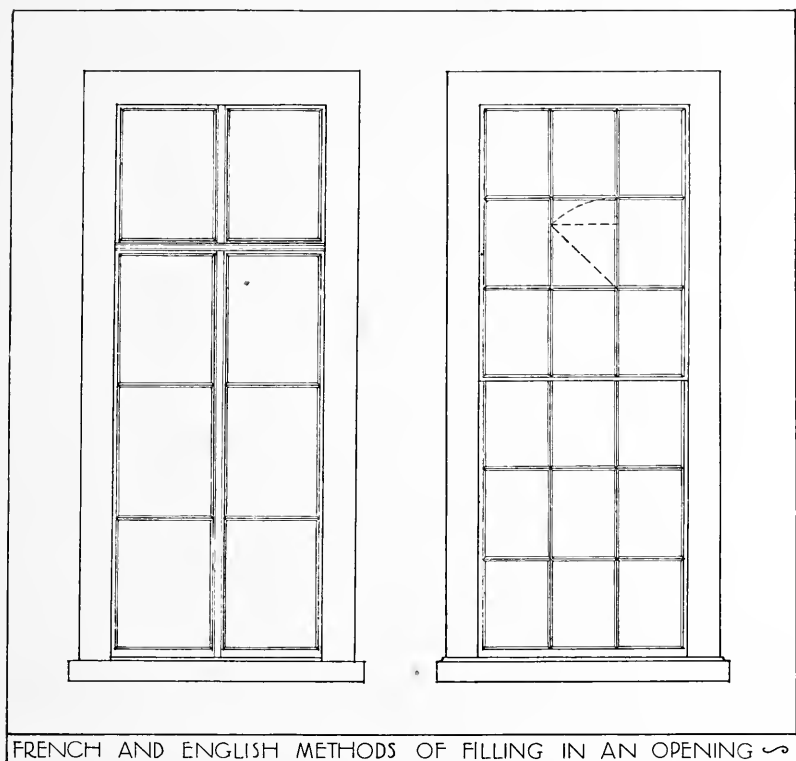


FIG. 153.

ix. 6. Theory and Elements of Architecture

two glazed doors, hinged and meeting at the centre. The cross formed in this way has given rise to the term *croisé*. The *croisé* is a true development from the mullion and transom of medieval times. The English method on the other hand

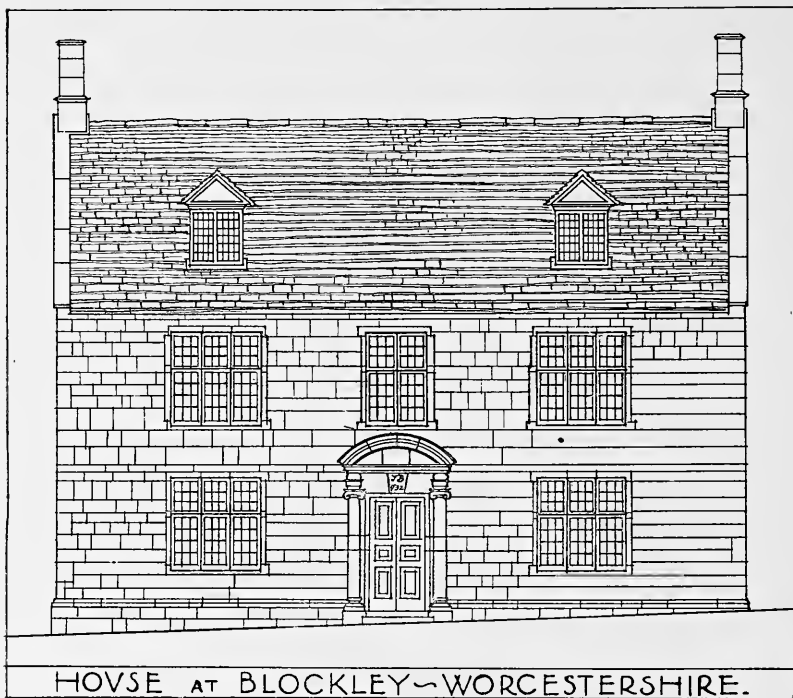


FIG. 154.—CLASSIC DESIGN DATED 1732, WITH MULLION WINDOWS. (After Field and Bunney.)

is to divide the window horizontally into an upper and lower *sash*.¹ In both cases window panes form further sub-divisions. Each method has peculiar advantages and a wise tradition behind it.

The mullioned window of the English Tudor and Elizabethan builders has already been referred to as an example of excellence in the more logical of the two types of opening (ix. 3). It was easily regularised and adapted into a classical

¹ See note next page.

design, and could give different widths on the same front. It was used freely in the country districts by builders of the Queen Anne and early Georgian period and makes an excellent treatment. We give an example measured and drawn by Mr Bunney (Fig. 154), dated as late as 1732. The oblong Georgian house with the adaptable mullion window is to-day one of the most useful and practical traditions.

The mullion window being so adaptable it is surprising to find, towards the end of the seventeenth and the beginning of the eighteenth century, in England and Scotland a break in the window design of monumental buildings having no parallel in France. Some of the early "Classic" buildings such as the Banqueting Hall, Whitehall,¹ and Ashdown House, Berks, at first preserved the central mullion directly from the Elizabethan. In some Queen Anne buildings to-day the sash and the mullion can be seen in the same design, the mullion windows relegated to the back top floor (Fig. 154*a*). But at the opening of the eighteenth century the sash window seems to have appealed to educated taste. "He showed us," says Lister, writing in 1699, "his great sash windows; how easily they might be lifted up and down and stood at any height."²

In cottages and in the attics and dormers of larger houses sashes were designed so that only the lower half was able to slide up, and a prop was provided for its support. Sometimes the centre light of a three-light mullioned window was given a sash while the two outer lights preserved their lead bars. A Kentish example of this is given in Fig. 154*b* in which the lower half of the sash is the only section made to open in the whole window. Sometimes two sashes were placed without balance weights on either side of a mullion, as in an eighteenth-century house at East Meon in Hampshire (same figure). At first a centre window-

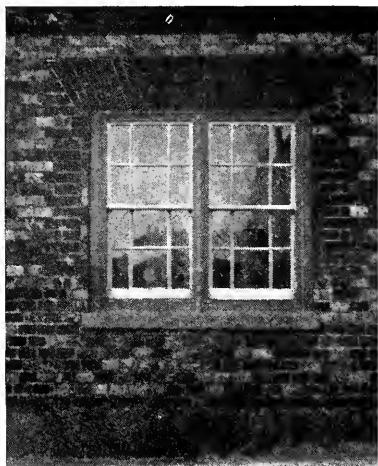
¹ The existing windows in the Banqueting Hall are sash windows inserted later. For good illustrations of the original windows with centre mullions see engravings in the collection of prints of old London, known as the Baddeley Bequest, at the London Library.

² Dutch "*sas*" meaning sluice, and French "*chassis*" meaning frame. Much early evidence of the use of the sash is documentary (see *Appendix, Note 9*). True sash windows are shown in the works of Daniel Marot, architect to William III., Amsterdam (1712). Marot was a Huguenot who transferred his services to William of Orange after the revocation of the Edict of Nantes. It would appear from Lister's *Journey to Paris*, 1699, that the sash window at that date was unknown in France and had been brought from England. The sash had probably been in use in England and Holland for a considerable period. An English example at Wickham Court with grooves cut out of the solid, dating from the time of James I., was illustrated in the *Builder*, 1847, vol. v., p. 279. The contact of Dutch and English taste under William and Mary may have served to strengthen it. In Holland William's palace at de Sael had mullions and shutters (see engravings by Post and Matthys) whereas at Loo the palace had, according to Walter Harris, 1699, sash windows throughout. For a comment on its origin in England see also Fig. 154*c*.



[H. B.]

FIG. 154*a*.—ROCHESTER. BACKS OF EARLY EIGHTEENTH-CENTURY HOUSES.



H. B.]

East Meon, Hampshire.



[H. B.]

Near Cranbrook, Kent.

FIG. 154*b*.—DEVELOPMENT OF THE SASH.

bar, as in the original windows still existing in Wren's Orangery in Kensington Gardens, preserved the æsthetic of the mullion. The centre window-bar to a sash window is still often designed but it causes inconvenience in the placing of the window catch which has then to be out of centre, and it has the disagreeable effect artistically of appearing to divide the window in two.

The development of the sash has many lessons in pure design. Its origin is not really far to seek. The sliding panel form of window or door was always known and exists to this day in the so-called "sliding casement" in which two frames slide in parallel grooves. These frames overlap and catch on the vertical bar exactly as do sashes on the horizontal bar (Fig. 154c). Identical catch fixtures are used. In this type the sides of the frame require to be heavy and act as strong stops able to take knocks. Hence the sides show wider than the top member. Now if this window is turned on its side we have the early sash. But the sash with pulleys also requires wide sides as boxes to accommodate weights, and these wide sides (same Fig.) are articulated on early sash windows (*see also in Fig. 34b*) with greater intelligence than in the later uniform surround. In English country towns eighteenth-century windows show a rich variety of type

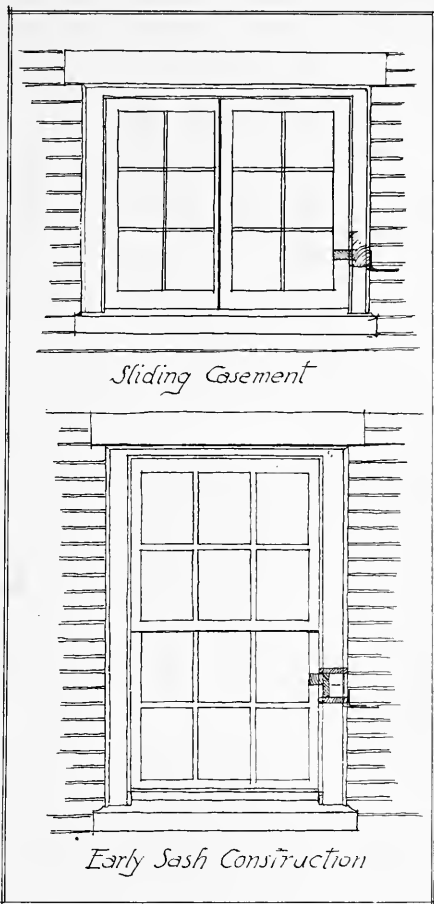


FIG. 154c.—SLIDING CASEMENT AND EARLY SASH.

IX. 6. Theory and Elements of Architecture

—as many as six different kinds can be seen in a single street in Hertford, all excellent, and exhibiting a freedom and inventiveness in design scarcely surpassed in the Middle Ages.

Nothing perhaps in the history of building is more remarkable than the conquest of Scotland by the sash window in the face of French and Jacobite

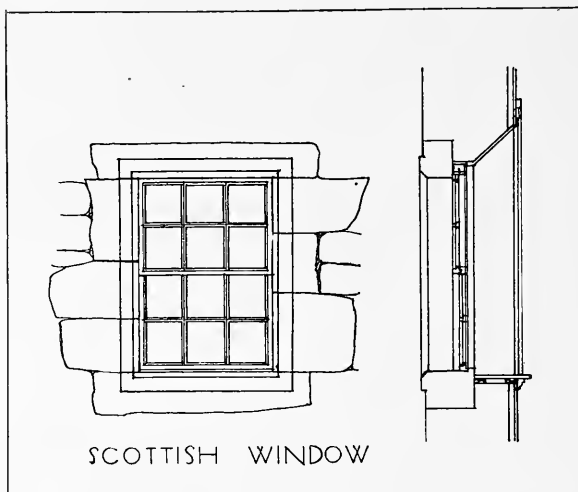


FIG. 155.—SCOTTISH SASH.

traditions. Probably its value in a windy climate, and some constructional predisposition, was the cause. The Scottish sash preserves, however, a character of its own, the sash frames are always set back about 6 inches from the wall face (Fig. 155) and do not show broad frames or a projecting sill as in English work.¹ This gives a character of its own to Scottish Classic (p. 275). The sash spread to Ireland and is almost universal in that country even in the smallest

¹ Mr R. W. S. Weir gives us the following information in regard to the old type of Scottish window : "The early windows had sometimes rather elaborately carved mullions and transoms (copes they were called). When glass was scarce and dear there were often shutter boards in both upper and lower halves and no glass at all but more usually the upper half only was glazed. One finds this early window still used to-day in stables and farm buildings."

houses. Holland, the British Isles, and the American and South African colonies were alike in their thorough use of the sash in classical windows.



FRENCH FRONT FROM BLONDEL.



ENGLISH FRONT FROM GIBBS.

FIG. 156.—HOTEL D'AUVERGNE. (From Blondel's "*Cours d'Architecture*," 1675-83.)
 VILLA AT SUDBROOKE, RICHMOND. (From Gibbs' "*Book of Architecture*," 1728.)

How different, when we turn from the intelligent provincial building of the eighteenth century in England to the monumental kind. The sash window tended at first to keep window frames small owing to the difficulties of hanging heavy frames. But this tendency was reinforced in the eighteenth century by the devotion of English architects and their patrons to Italian models having relatively small window openings with large architraves. The reproduction in Portland stone by English architects of the compositions of Palladio the Italian—compositions having window-openings suitable to the Italian climate, but not at all suitable to the English—led to unsatisfactory results. English windows were too small. The French classical builders on the other hand, although they studied Vignola, never lost touch with their native tradition. Thus they have preserved the window with mullion and transom to this day just as they have preserved the high-pitched roof. Moreover, the French window was not reduced in size but in nearly every period its treatment was broader than the contemporary English. To illustrate this a French design from F. Blondel of the end of the seventeenth century is compared to an English design from Gibbs of the beginning of the eighteenth century (Fig. 156).

A sheet of typical French windows taken from actual examples—not to scale—(Fig. 157) may be compared to a sheet of English (Fig. 158) also taken from actual examples—to scale. The French preserve the mullion idea throughout and preserve also the primitive feeling that door and window are essentially the same.

In any comparison of the architecture of the two countries it must be admitted that the French Renaissance builders, as compared with the English, evolved a more useful window, and as we shall see in a later volume a more useful staircase; also we have already seen that the deliberate maintaining of the high roof in France gave to their Classic style an elasticity and interest lacking in England.

7. *ANGLO-PALLADIANISM*

It is not just however to criticise, and criticise only, the Anglo-Palladian phase. That phase is an anomaly that is dangerous to dismiss without some understanding. How did it come about that while Georgian country builders and artisans in England and in America were refining and developing a consummate art both in architecture and furniture, highly-trained architects in England were imitating Italian models, for a generation and more, without use or art. We

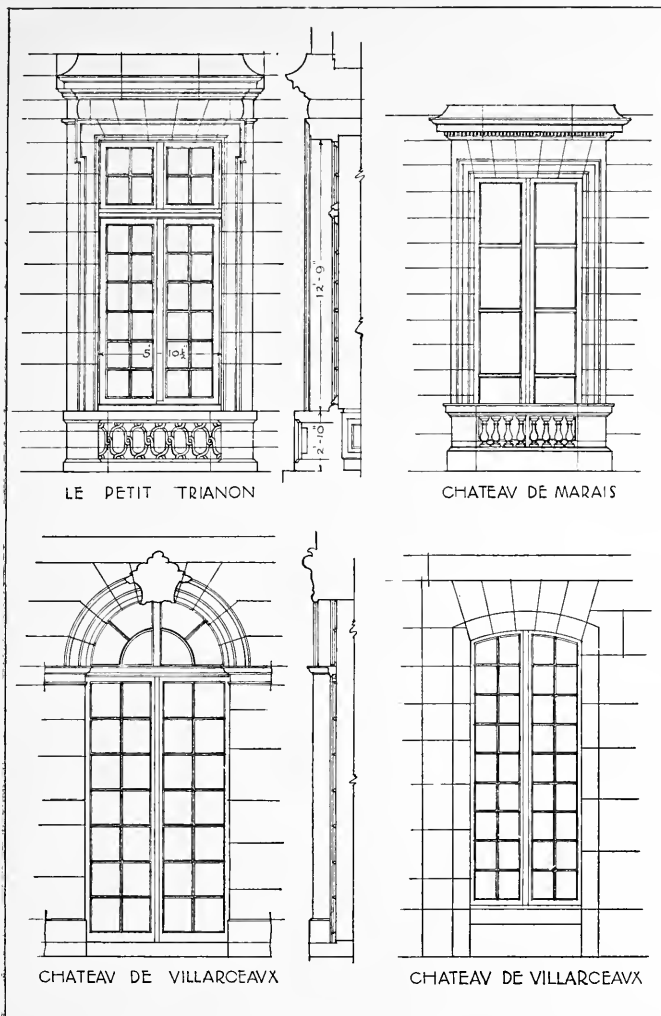


FIG. 157.—EXAMPLES OF FRENCH RENAISSANCE WINDOWS.

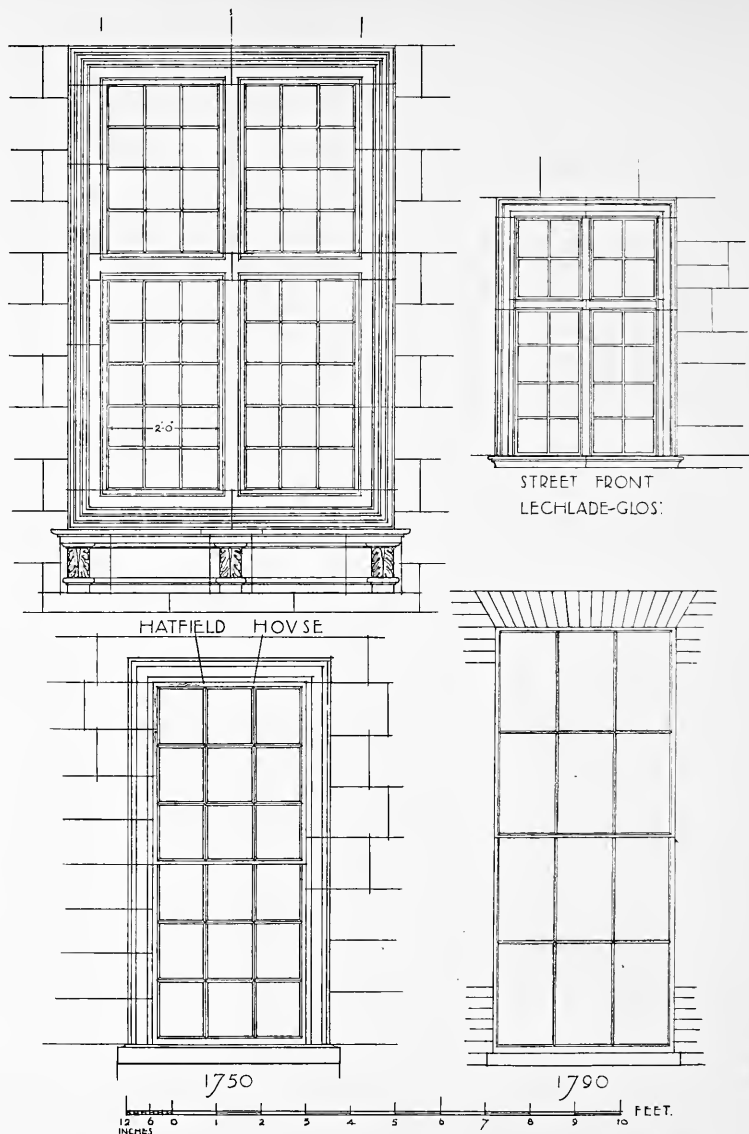


FIG. 158.—EXAMPLES OF ENGLISH RENAISSANCE WINDOWS.
[The Hatfield House example is not to scale.]

have only to compare as shown above, the provincial window treatment with the orthodox Palladian to note the difference. English architects suddenly ignored their own window traditions (Fig. 154) for an Italian opening filled with a Dutch frame. In the same way we have noted the variations in roof fashion in England (vii. 8)—variations that occurred without apparent regard to tradition or common sense. These two facts are examples of an instability in “taste” which has been explained by a dualism in our climate and race character (ii. 6)—a placing side by side of northern and mediterranean impulses neither of which gain an ascendancy but each of which in turn is reinforced by one or other of the factors in our alternating climate. The English mediterranean impulse seems to take two forms. *First* an instinct in building for sobriety, horizontality, and a simple equilibrium; this we see (in periods of æsthetic calm) in the horizontality of Elizabethan and Perpendicular buildings and in the eighteenth-century provincial buildings we have just been considering. *Secondly* an attraction on the part of Englishmen, for the genius and climate of Italy. In the first we see a natural English classicism which has interested or attracted Italians from the Roman Agrippa and his son-in-law Tacitus, to Rosetti and to Mazzini; a kind of moderation—a beauty of equability—that can be tasted in the English landscape, especially in places where the oak and fern are undisturbed. In the second we see a personal emotion—a preference that has long preserved a political sympathy for Italy, and has based and maintained our education upon the Classics. Anglo-Palladianism must be recognised as a symptom in art of that attraction exerted by Italy and Italian culture on Englishmen of the mediterranean cast—an attraction that has no parallel action upon France and upon French minds. In the field of *expression* English literature as well as architecture shows this attraction. We have referred already to Bramshill (Fig. 123) as a building of a kind of Shakespearian Classic. It well sums up the native genius of Elizabethan England. But Milton and Inigo Jones—both heirs to the wealth of that great period—leave all behind them, journey to Italy and make the Italian language their own. In Italy they found a higher power of “the Classic,” a more universal expression of that kind of beauty with which as Englishmen they were already familiar. And returning to England, each of these artist-students proceeded to impart a more distinct classical quality to the forms they handled. With what results we know. Neither our masonry nor the structure of our language will come to the sharp edge or carry the load of antique knowledge implied in the Latin or Italian. The compound of our climate and of our race has another average of qualities. Hence the greatest English artists can carry English classicism very far and can

WILTON HOUSE
The South Front.



FIG. 159.—WILTON HOUSE, WILTS. SOUTH FRONT. (From Triggs and Tanner.)

IX. 8. Theory and Elements of Architecture

do things with English materials—unifying conflicting elements—in a way that lesser minds cannot do. Compare and contrast the works of Inigo Jones and of James Gibbs. Our greatest and most characteristic architecture is neither Italian nor Northern. It has a quality and a flavour of its own as in the work of Wren. But the English architect has always to reckon with the English classical instinct and with the emotion for Italy liable to confront him at all times in his practice and make beguiling and illogical demands upon his art.



[H. B.]

FIG. 159*b*.—ATHENÆUM CLUB, PALL MALL, LONDON.

8. SPECIAL TREATMENT OF WINDOWS: BALCONIES

The Italian architect Scamozzi (seventeenth century) liked to mark the centre of a rigidly symmetrical building by a special window shape, and for this purpose frequently used a large round-headed opening now known as a

Venetian window. Inigo Jones was much influenced by Venetian Classic, and designed at Wilton a window of this kind (Fig. 159). It should be used as a focus, or to mark end pavilions.

In England in the latter half of the eighteenth century a freer school of design under men like Brettingham, Adam, and the Wyatts, increased the size of the window in classical buildings as in Trinity House, London, and often used wide proportioned semi-circular headed openings with fine effect. Good examples are to be seen in the Royal Society of Arts building Adelphi, and in Harewood House in Yorkshire. At Harewood the large windows are used to emphasise the wing pavilions, and like a true Venetian window are more fitted for that purpose than to be used in a row where they are liable to lose their value, as in the County Assembly Rooms, Leicester (Fig. 159*a*). They can be used in repetition to give a specially strong rhythm when such a rhythm is required, as explained in the next section and shown in Fig. 160.

Balconies placed in front of windows if heavily designed will alter the pro-

portion of the opening. They should be of ironwork or designed as a light breast within the window opening if the whole oblong is to remain effective. In the case of heavy balconies the window opening will read from the top of the balcony and should be designed in that way. In the sheet of French windows (Fig. 157) the upper two examples have balconies. The Petit Trianon window has been designed to read from the top of the balcony but in the example from the Chateau de Marais shown in the same figure the balcony cuts into the design. In Barry's Athenæum Club, Pall Mall, a fine cast-iron balcony traverses the fronts without destroying the proportion of the windows (Fig. 159*b*). In this building French *croisé* windows are used above and English sashes below.

Windows can also be grouped together by means of balconies uniting two or more. The French use of wrought ironwork for balconies and breasts (Fig. 159*c*) is an admirable tradition in their city architecture. It provides a pleasant contrast to masonry and gives a useful access to windows for cleaning purposes (ix. 12).

But balconies in cities must not project more than a few inches from the wall face or they will obstruct the area of the sky seen from the window next below it and diminish its efficiency (ix. 12),

9. WATERPROOFING OF WINDOWS

A building in a rainy climate has to be envisaged as frequently covered with a film of water travelling downwards and adhering upon its whole surface. Window heads, like door heads, require special protection against this

film which will penetrate all joints, and we have seen that this requirement enters into the first principles of door design (p. 288). For this purpose the classical hood or small cornice over windows and doors was evolved and was succeeded in medieval times by the drip mould. Some form of protecting head having a "drip" able to throw off the water is an essential part of every window design

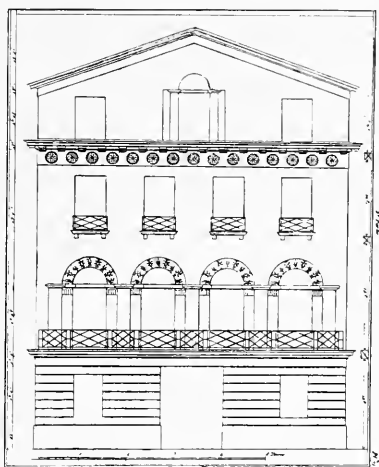


FIG. 159c.—FRENCH USE OF WROUGHT
IRON-WORK.
(From Krafft and Ransonnette.)

unless the window comes close under a cornice or projecting roof. Drip moulds and hoods over openings within doors are wholly meaningless. Similarly the sill beneath the window in English practice is provided with sufficient projection to

have a "drip" and thus help to shield the window head next beneath it, a practice not followed in Scotland, and often with inconvenient results.

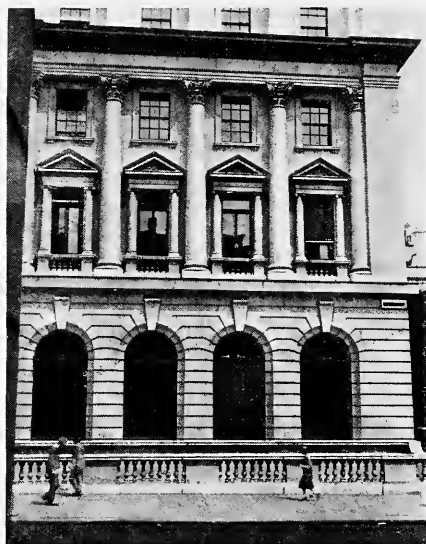


FIG. 159d.

[H. B.]

10. FENESTRATION AND SUB-DIVISION

Fenestration, or the arranging of windows in a design has already been touched upon (viii. 3). In a quite plain façade the doors and windows can themselves form a pattern able to give a monumental character to a building, as can be seen in our illustration forming a headpiece to Chapter VIII. But the making of the pattern admits of a few elementary rules which should be understood first if they are to be used with greater freedom later on. When windows of

classical proportion are designed side by side a good spacing is to have piers or wall spaces between windows at least equal to the width of the window. But care should be taken to keep the window dressings within limits or they will appear to reduce the wall spaces. The heavy architraves on many twentieth-century English windows are relics of the Anglo-Palladian window tradition and are only possible with relatively small windows and wide piers. When used with narrow piers they give a weak effect. The wall space on the angle of a front should be at least equal to the wall space between windows and if possible wider; this again is for the sake of the ordinary appearance of stability which should not be lost sight of.

Since it is the voids and solids and their relationships which are the real

elements of the pattern the solids should not be diminished by superfluous ornament which produces half-tones generally ineffective in our climate. When this ornament is itself quite meaningless, as is the case when rows of pediments are embellished with key blocks, or small columns are placed on either side of every window in a row (Fig. 159*d*), the result is liable to be ugly.

Symmetry in fenestration need not be carried to pedantic extremes.¹ It is quite possible to arrange a row of large windows equally spaced and constituting the chief feature in the design and at the same time to place subordinate windows in positions not uniformly related to the large windows. If

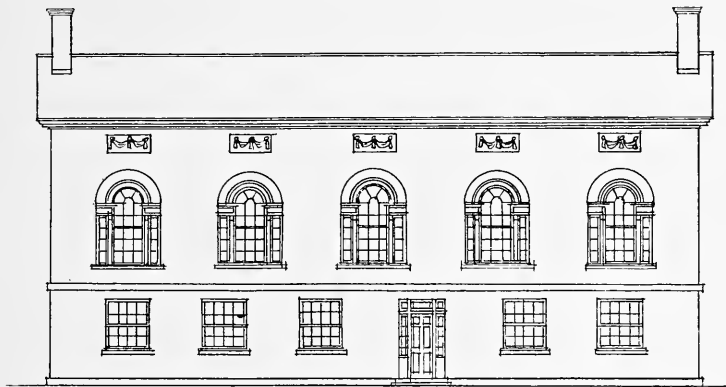


FIG. 160.—HAMILTON HALL, SALEM, MASS. (From Ware's "*The Georgian Period*.")

the large windows are sufficiently dominating the design will have a unity in spite of minor irregularities (Fig. 160). Scotland Yard designed by Norman Shaw is also a good example of this.

Windows can give a rhythm to a front if they are emphasised alternately, as in the fine house in the Rue de la Prefecture, Dijon (Fig. 161), and by this means it is often possible to economise in wall space.

We have seen how the Classic builders of antiquity used grilles, in their fanlights and semi-circular windows, in order to sub-divide openings (ix. 4). In

¹ Scamozzi in his text-book lays it down that not only must the windows on the right exactly equal in size and number those on the left but also that windows on the front must exactly correspond to those on the back of a building!

IX. II. Theory and Elements of Architecture

the same way the pane of glass which is the modern sub-division of the window, provides a unit of shape which is essential in a design for comparing

the parts and realising the whole. For this reason the window pane must be approximately the same size throughout the building. From the point of view of pure pattern the unit of shape is as important as the interval in music. A good unit shape for a pane is a square in width and in height the diagonal of the square (see the English example in Fig. 153). Some architects prefer a taller pane. Panes are equally important for sash and casement windows. Where they have been removed, as at Hatfield House or on the ground floor of the Athenæum Club (Fig. 159*b*), and replaced by plate glass, the building has suffered. Plate glass involves a much larger unit and any design which is based on that unit ought to be larger and something different in character to that based upon the ordinary pane. The



[J. E.]

FIG. 161.—DIJON. HOUSE IN THE RUE DE LA PREFECTURE.

French window with its *croisé* divisions is more suited to plate glass than the sash which divides the oblong exactly in two.

11. RELATIONSHIP OF WINDOW AREA TO FLOOR AREA

The much debated question of large or small windows for living-rooms is, within limits, a question of taste. How far shall warmth be sacrificed to light or to a fine prospect? Too large an expanse of glass cools down the air in the room rapidly but this defect may be obviated by central heating.

The heating system should always be considered in relation to the design of windows.

Sir William Chambers in his chapter on windows (6) pays special attention to lighting: "In regions where gloom and clouds prevail eight months of the year it will always be right to admit a sufficiency of light for these melancholy

seasons.”¹ He finds Palladio’s proportions unsuitable for the English climate and refers to an excellent rule given by James Morris to the effect that the window area should be equal to *the square root of the volume of the room*. (7) This rule, much neglected in large mansions when it was first enunciated in the Anglo-Palladian period, is followed in effect in modern practice; it is roughly equivalent to a fifth of the floor area, and therefore provides more light than the minimum insisted upon under the L. C. C. regulations, namely, one-tenth of the floor area.

But these early rules did not take into account the obstructions to light common in our great cities. These we must glance at since they directly influence design.

12. AMOUNT OF LIGHT ADMITTED BY WINDOWS

We have said (p. 317) that windows only admit a fraction of the “sky brightness” or actual light available from the whole horizon of sky. Daylight illumination within a room is usually in modern practice “expressed as the ratio between the brightness of a white card laid on an unobstructed window sill (which is very nearly half the sky brightness) and the brightness of the same card placed at any interior position.” (1) The ratio between the two is known as the “sill ratio.” Now the sill ratio of seats remote from a window is often exceedingly small. “The sill ratio of the worst lit desk in new classrooms in this country was found by measurement to be one per cent.” (1) This is due to the amount of sky necessarily obstructed in cities. The efficiency of a window in England as a source of light depends on the amount of sky framed within it.² This depends on the height of the window head above the floor and on the obstructions. But obstruction may be at the side as well as opposite and above.

A smaller window in an unimpeded wall may give more light than a large window in the re-entrant angle of a building. This applies specially to semi-detached houses. Also the greater the height of the window head above the floor in city buildings, the greater the efficiency. Sometimes lintels can be splayed and thereby give an appreciable increase of visible sky as has been done in a number of streets in the town of Bath. Balconies in this respect are a danger. A good rough rule to follow is that at table height above the floor at any point in the room there should always be some portion of sky visible through

¹ Chambers gives a rule of his own :—“I have generally added the depth and height of the rooms on the principal floor together and taken one-eighth part thereof for the width of the window.” (6)

² For reasons given on p. 24 the efficiency of an Italian window does not depend on this fact.

the window. In the country, rooms are generally better lit owing to the greater field of sky, but here again tall trees within fifty feet of the house may destroy the efficiency of windows. A line drawn on section from the nearest obstruction through the glass line of the top of the window and down to table height above floor level will show the limit of good lighting (Fig. 162).

In large industrial cities a general rule for domestic buildings in "ancient light" cases is that no obstruction to the sky shall be built nearer than a line given by an angle of 45 degrees from the head of the lowest window. But this is inadequate. The line should be taken from the sill, not the head of the lowest

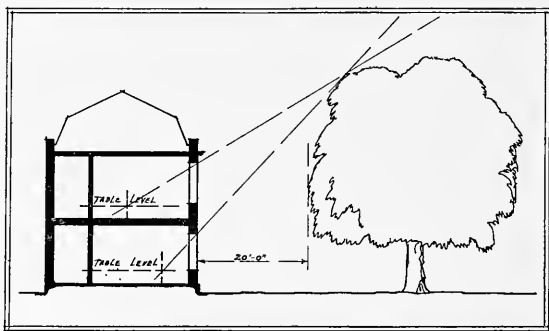


FIG. 162.—DIAGRAM SHOWING AMOUNTS OF SKY OBSTRUCTED AT TABLE LEVEL BY A TREE 20 FEET FROM A HOUSE.

window, in order to insure a larger field of sky at the head. Prism glass can be used to reflect light from the sky but the glitter is unpleasant. The cleaning of windows is an important point and for this purpose easy access to windows is necessary, and regard must be paid to the requirements of the professional window cleaner. This will influence design.

During the nineteenth century the annual death roll was considerable among domestic servants whose duty it was to lean out, insufficiently protected, and clean the outsides of windows. The professional window-cleaner now requires easy access to the glass in order that large plate-glass windows in cities shall be cleaned frequently and rapidly. Modern windows in iron frames are frequently designed so that both surfaces are accessible from inside. In exceptional cases narrow iron balconies or breasts and brackets could form part of the

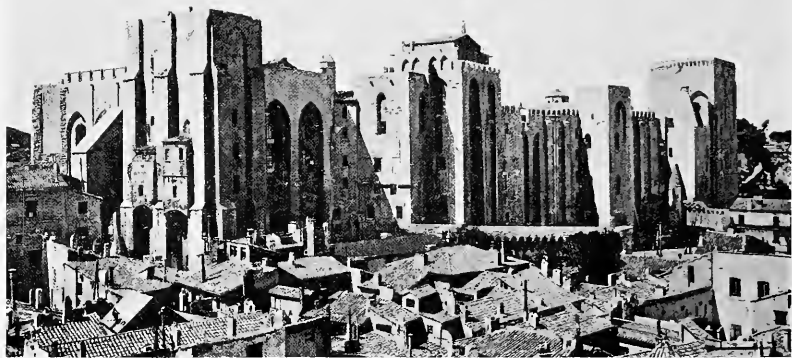
exterior design. They might be developed into interesting features, in the way Parisian ironwork is treated (Fig. 159c) upon the fronts of town houses.

13. EXCLUDING OF SOUND BY WINDOWS

Street noises should be carefully considered in designing windows on plan. Important board-rooms or committee-rooms should not have windows made to open on noisy thoroughfares but should be designed on internal courts or with top lighting. The windows on second, third and fourth floors are liable to be noisier than ground floor windows owing to reflections from brick or masonry walls opposite. If windows are to exclude sound they should be of thick plate glass in rigid and heavy frames. For this reason sash windows are not so efficient against noise as French windows which close more firmly against a mullion, and wooden frames are less efficient than iron. Double windows of thin glass are less protective than a single window of $\frac{3}{4}$ -inch plate glass. Since the window may not be opened in business hours if noise is to be excluded a special ventilating system is necessitated.

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AVIGNON. PALACE OF THE POPES.

Chapter X

SOME APPLICATIONS OF FIRST PRINCIPLES

1. *THE FIRST STAGE*

We have now reached a particular stage in our study: we have before us the first and most important building elements, and also some idea of how they were used by the great builders of all periods. There still remain other elements scarcely less important such as arch and dome, staircase and fireplace, and we have still to consider the contribution of the trained builder—how he developed mouldings and orders, observed plant-shapes, invented patterns and deduced laws of proportion and composition. This second stage is reserved for another volume. But we have already in walls, roofs, openings, and in the idea of fine structure, material for the greatest art, and at this stage certain principles can be discerned and studied more easily.

A general review of the ground covered shows first that there exists a strong continuity in the history of structure. The physical dimensions of a man, the bending and crushing strengths of masonry and timber, remain the same. We have still to build with bits of the earth's crust under laws of gravity, and the

Some Applications of First Principles x. 2, 3.

common materials that have always been used—brick, stone, concrete, timber—are likely to remain in use. There is little real evidence that for average purposes any others are cheaper or better. Therefore an architect must understand first the traditional materials because when all is said nine-tenths of his work is likely to be in them.

Similarly there is a continuity in those other factors which we have studied in this book. Protection from climate is still necessary and the influence of climate upon mentality still exists. Man still loves comfort, yet has to die, and still desires to erect monuments in the face of death. An architect must understand first these great continuities before he can give to them a new interpretation or express towards them a new attitude of the spirit.

2. *VALUE OF SIMPLICITY*

Simplicity has a special value in architecture. We have said that a building can convey emotion by mass alone—that is simply by the presenting of large solids to the eye in a bright light, and we have seen that mere size has been used by certain builders for a definite purpose (v. 2). But mass is most effective in its simplest terms. A building is more open to criticism—whether ugly and inhuman, or beautiful and reasoned—if it is plainly treated; and conversely, a multiplicity of meaningless “features” in a style destroys all emotion whatever and teaches citizens to shut their eyes. If the expensive city buildings, so common in our streets, were not obscured by orthodox “features” and “ornament,” the bad ill-reasoned building would at once be recognised and condemned, and on the other hand many finely planned ingenious buildings would shine out with unexpected beauty.¹ An architect should know his job well enough to make a quite simple building interesting. Architectural elements suffer from being in themselves the most familiar objects on earth and therefore to sophisticated eyes without significance. But we have tried to show that there was once and is still an emotion proper to each element—an emotion of wall, of roof, of door, of window. The art of the builder is to use first that elemental material before any other.

3. *EXPRESSION OF PROTECTION*

Consider the case of wall. In modern life certain buildings exist first to house and protect precious objects such as pictures, archives, and books, from fires

¹ Compare the front of the Russell Hotel with the back in Herbrand Street, compare also many other “backs” in London where “features” were not called for, with the corresponding fronts.

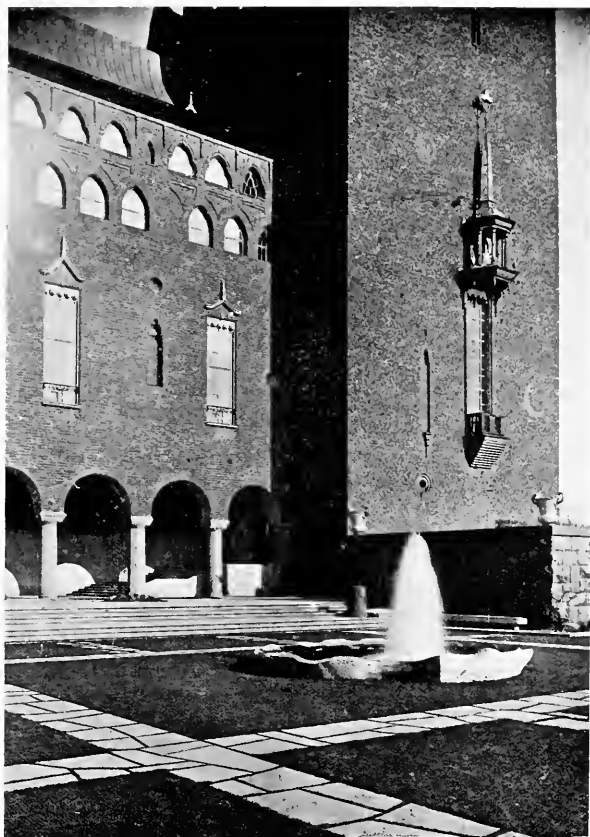
x. 4. Theory and Elements of Architecture

and hazards. These buildings are—picture-galleries, museums, record offices—buildings in which the roofs are frequently used for purposes of lighting. It is wrong to use for these buildings forms developed for other functions, to use for instance Greek temples such as the British Museum, Romanesque cathedrals such as the Natural History Museum, South Kensington, or Florentine Palaces such as the National Portrait Gallery, London, and rely on an interest of association or romance when the direct emotion conveyed by a powerful protecting wall—the first and obvious element—is ignored. Since the roof in such buildings is subordinate, is in fact a window, it is legitimate to treat the wall as a vast spectacular curtain enclosing a series of halls. The Record Office in Chancery Lane is by no means a bad example; but it happens also that these conditions are expressed by a famous building—the Palace of the Popes at Avignon (headpiece to this chapter). Roof values in this building are ignored and the whole effect is made by strong square wall masses, obviously expressing the protecting of something within. This building should not be taken deliberately as a model for a National Museum or Muniment Room, but it should be noted that here is a good expression in the simplest plastic terms of the *idea* of such a building—the idea of protection by wall.

4. TEXTURE

The beauty of cut stones and granular surfaces proper to a wall has been touched upon hitherto only briefly. The apparently accidental beauty in the texture of a rubble wall, as for instance in the old Simplon Hospice (Fig. 165), cannot be achieved by the modern architect without considerable craftsmanship. It can only be arrived at by the co-operation of the hand of the builder with his brain, not by his brain alone. Yet when it is present in a work it makes an immense positive contribution of a kind that nothing else can make. This sense of texture as a human element in the best building came to be recognised in England at the end of the nineteenth century and was best achieved in practice by such universal craftsmen as Ernest Gimson.¹ A standard was set in this respect in England which has had far-reaching results and at this day distinguishes the best English architecture from the best French. But beauty of surface is a contribution only and can never of itself compensate for the lack of intellectual qualities. It is a kind of grace that comes from the true synthesis of brain and

¹ It can also be seen deliberately sought for and achieved in the work of W. R. Lethaby, R. S. Weir, Ernest Newton, and many other members of the Art Workers' Guild. It is frequently—though not invariably—joined with a sympathy and concern for the building operative and the part he ought to play in fine architecture.



[F. R. Y.]

FIG. 163.—STOCKHOLM TOWN HALL. TOWER AND ARCADE.
(*Ragnar Ostberg.*)

hand in building, and should be used to enhance the intellectual qualities. It can be seen thus consciously used and with enormous effect in the new Stockholm Town Hall by Ragnar Ostberg (Fig. 163).

Deliberate simple contrasts in wall colours, however, are easier to come by and are not explored as they should be. Wren designed monumental buildings as often in brick and stone contrasted, as in stone alone. In Hampton Court the most formal design is enlivened by a plain contrast in materials. A

good example is also found in Keswick Town Hall (Fig. 164) where a rubble wall white-washed is contrasted with stone quoins and dressings.



FIG. 164.—KESWICK TOWN HALL.

5. *DESIGNING IN THREE DIMENSIONS*

We have seen that when a roof is added to a wall both structure and art are at once made more difficult and more interesting (vi. 3, vi. 4). Artistically the result is to include the third dimension as an instrument of design. To use the cube of a building for an æsthetic purpose is simple but not

always easy. Certain rules will serve as a help, but only as a help, in design. First the size of a building, that is to say the angle that the eye has to include in the view of it, ought not to be too large. The size of many medieval cathedrals often prevent their being read in three dimensions unless they are upon a hill or visible from a vantage point. We have also seen that depth of reveals to windows and doors are necessary in order to give a sense of mass or solidity to a building. In Figs. 82, 83, 127, 128, we have shown buildings reduced to their simple plastic terms. Though they are not thus seen by the general public, that is how they should be to the architect and that is how he should see his own designs in his mind's eye.

A greater satisfaction can sometimes be conveyed by quite simple buildings having a fine plastic character than by the most accomplished façades. The old Simplon Hospice, already noticed (Fig. 165), consists of the simplest lodging for the night for the largest number of wayfarers to which certain bell and light beacons have been added for a purpose. The simple cube of the building—arising primarily from these necessities yet also consciously emphasised and enjoyed—has great beauty. The pleasure given by its wall texture has already been noted; also it is worth observing how the structural principles discussed in (viii. 5) are illustrated in its doors and windows which make a quite definite contribution to the total effect. We may wonder how so apparently simple a building can give so much pleasure. The reason is that whereas a modern façade may have all the expensive attributes associated with “style” and yet may convey none, or only one, real emotion, this building makes use of all three—that of wall, of cube, and of opening. The Keswick Town Hall (Fig. 164) on the other hand has a beauty of wall and cube but its openings though excellent as pattern are shallow and do not contribute as fully as they might.

In the Stockholm Town Hall (Fig. 163) windows are used with shallow reveals for a purpose—the glass brought forward catches the light and has a beauty of its own, as well as emphasising by its brightness the pattern made by the fenestration; but to compensate for this the arcade openings below give



FIG. 165.—OLD SIMPLON HOSPICE.



FIG. 166.—BALFUG CASTLE, ABERDEENSHIRE.

the necessary sense of depth. This figure also well illustrates the wonderful refinement of detail in this building and how the plainness of the wall is used as a field against which the most delicate windows, niches, and canopies are enhanced. Compare the use of the south wall of the Erechtheion by the Greeks as a field for the Caryatid porch (Fig. 50f).

In Balfluig Castle (Fig. 166) there appear to be no windows at all in the humanist sense; but great ingenuity in the defending of entrances and angles, and the strongest protective structure, have produced a shape of great character; the slit openings and the harled walls are monstrous yet the mass is noble and beautiful and conveys great satisfaction to the eye. In such buildings as Balfluig and the Simplon Hospice we have, as it were, the bed-rock of nordic architecture both in respect of its use and art; in them nothing superfluous or borrowed has survived, they reveal the native talent of a people. In the words applied by Goethe to the Greek masterpieces—"Everything arbitrary, everything self-conscious disappears. There is Necessity, there is God."

In "modern" buildings the same economy, the same beauty, can be achieved but not by Necessity alone. It is often achieved in so-called "utilitarian" buildings but the builders

must have enjoyed and taken a pride in their work and added to it instinctively the necessary emphasis and wit. In Fig. 167 we show in outline an American barn with silos attached. To the designing of buildings of this kind in the United States considerable thought and con-

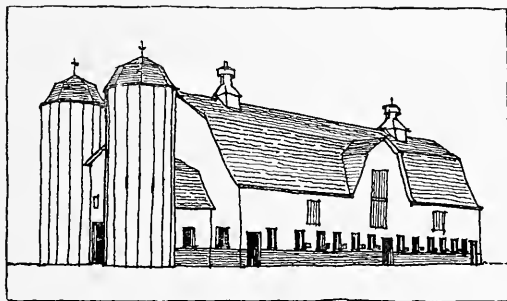
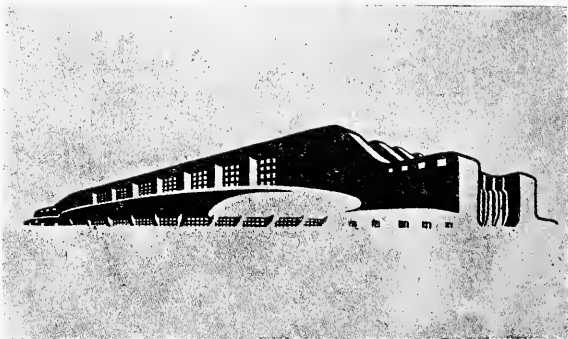


FIG. 167.—AMERICAN BARN, WITH SILOS ATTACHED.

siderable talent has been given and the shapes produced are of the finest. They exhibit also a true national talent. To this expression of modern Agriculture let us compare a corresponding expression of modern Industry. In Fig. 168 two designs by Mendelsohn are shown for modern German industrial buildings. This architect seeks deliberately to express "the will of an epoch" in his buildings in addition to the more fundamental values of "space and



Sketch for an Optical Factory.



Sketch for an Aerodrome.

FIG. 168.—TWO DESIGNS BY ERICH MENDELSON FOR INDUSTRIAL BUILDINGS.

(From Mendelsohn's Structures and Sketches.)

surface.”¹ He feels the immense new material provided for him as a plastic artist by modern science and technology and desires to use it to the full. He finds a cause for the shapes he produces, in the functions and practical requirements of industrial buildings and in the physical nature of “modern” materials. The shapes convey the brutality of modern Industry as well as its power, and suggest that its epoch still requires educating in those values of humanity and contemplation that in this book we have studied side by side with the scientific. The shapes also convey very strongly the personality of a powerful artist. This is permissible in architecture when the artist is great—that is, has something of the universal in his vision—but is not permissible to imitate. A small mind will not become great by changing its mode from “Classic” to “Modern” or by using cantilevers instead of beams.

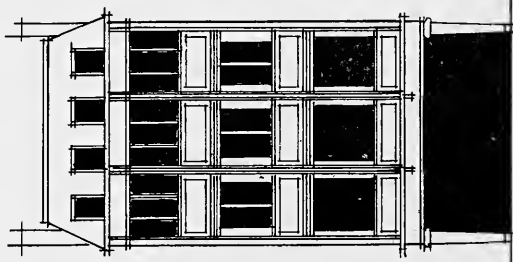
But the desire for a new equilibrium—a new adjustment of ancestral forces—is visible in Mendelsohn’s shapes as in the Einstein Tower at Potsdam and gives them value as experiments. Architecture advances, as we have said, by very slowly making use of the best and most universal experiments.

6. EXPRESSION OF STRUCTURE

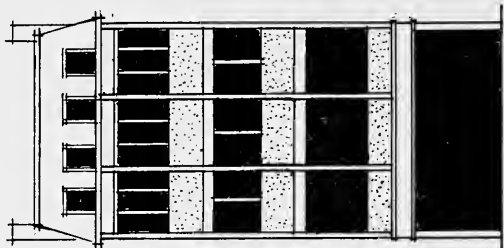
In distinguishing the “panel” from the “course” in wall construction (iv. 4 and v. 8) stress was laid on the fact that the panel is more suited to steel-frame or reinforced concrete construction because that construction is in the nature of a joinery rather than a masonry. To-day, in city building, we are in a transitional era in which a lintel tradition is being carried forward into steel and reinforced concrete. Therefore experiments in the articulation of structure in the past by skilled builders of lintels—Egyptian, Greek, Medieval—are worth knowing. If they were known, many architects would not still be seeking—ostensibly for æsthetic reasons—to express an essentially jointless structure by the semblance of “rustication”—an instrument evolved by Romans and Florentines for quite other artistic ends. Such architects are ignorant of the æsthetic experiments that concern their problem, and may spend their lifetime learning with their client’s money what a little study could teach them in a day.

Consider a city building with a shop front. In Fig. 169, in the centre diagram is shown the bare frame and filling necessary. Assume that the clients would like as much window space as possible on all floors, and will have no screen piers

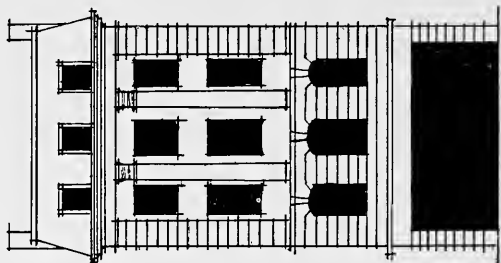
¹ Mendelsohn, Erich *Structures and Sketches*, p. 3. Transl. from the German by H. G. Scheffauer.



Structure Emphasised



Steel Frame



Structure Confused

FIG. 169.

in front of their shop window. Let us apply to this problem the kind of logic the Greeks would have applied. First the structural lines give certain limiting conditions, and limiting conditions are of first importance in an artistic problem. The steel-frame gives certain major and minor members, and certain screens are necessary which are shown dotted in the figure. The whole structure is set upon two end supports; the characteristic stress is therefore a bending stress occurring in a number of obvious lintels. The expression therefore, should be the expression of lintel structure rather than any other and the art will consist simply in making something beautiful out of these elements. In the left-hand diagram (Fig. 169) the lintel structure is emphasised; in the right hand it is disguised. In the left-hand diagram the load is recognised as concentrated upon the two piers on the ground floor. Concentrated load has been well expressed already by Cretan and Mycenaean builders in a column that tapers downwards.¹ Above these two piers the main lintel is emphasised upon which the four uprights are carried. Between the uprights there are lesser lintels, and the openings left permit of breastings which are really panels and are made to look like them.² The articulation should be as simple as possible at all stages. The steel can be protected from the weather by brickwork or thin slabs of masonry. The panels can be of plaster painted a bright colour or of tiles. The brightness of the protecting surface over the whole building is of first importance (ii. 3) because in this kind of building it is likely that the beauty will be the result of a smartness and grace in its quality, and this requires bright expanses and points of colour.

In the right-hand diagram of Fig. 169 is shown the common method of protecting and at the same time disguising the structure. No attempt at articulation is made; therefore there are no straightforward limiting conditions and the artistic problem becomes ten times more difficult. The æsthetic proper to a lintel system is here ignored and instead that derived from the massive Italian wall with its distributed loads and its "rustication" has been adopted. But rustication, which is a means of expressing *distributed load*, here fails—very naturally—to express or even disguise the *concentrated loads* that actually exist. Rustication of the piers of the ground floor is quite meaningless and equally

¹ At Knossos, as seen in Sir Arthur Evans' reconstitutions, concentrated load was admirably expressed by the Minoans in their cypress columns. These columns had a great cushion under the lintel (Fig. 45*b*) and taper downwards delivering the load often upon a square block of serpentine. The downward taper is used to-day by furniture makers. The Greeks reversed the taper when they converted columns from wood to masonry.

² For experiments in breastings and windows see Egyptian (Fig. 146*a*) and Byzantine (Fig. 150*b*).

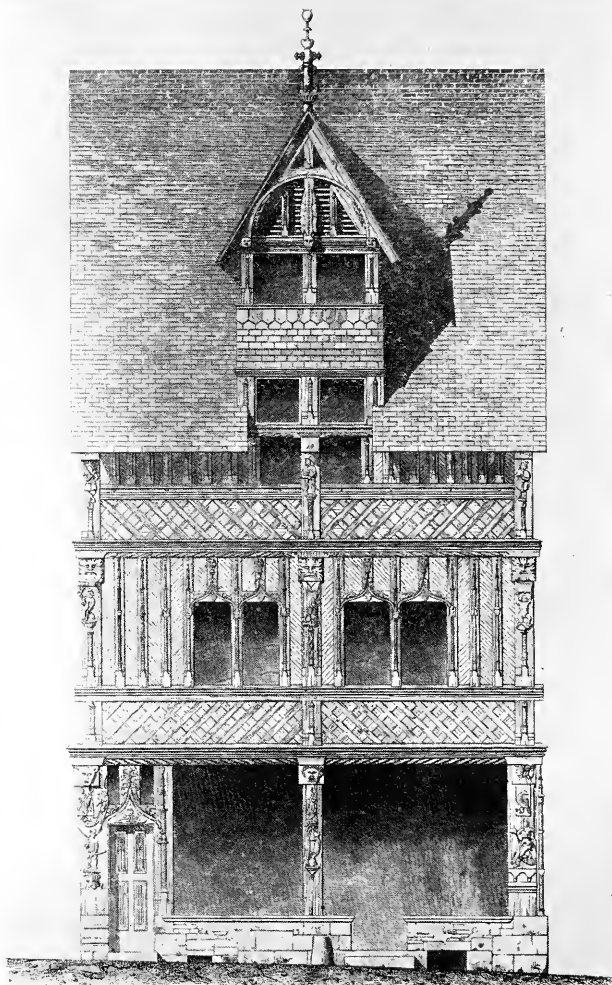


FIG. 170.—LISIEUX. A MEDIEVAL SHOP. (*From Reynaud.*)

so is the placing of columns (which suggest concentrated load) in the upper part of the building instead of at the bottom. Instead of the filling in of openings by a breasting, arch openings on the first floor with imaginary key blocks are used. The rustication over the main surfaces seeks to express a massiveness of material which does not and cannot exist. From these curiously compounded works of artifice it is not surprising that the quality of beauty has frequently evaporated.

Some convention is necessary for the clothing of any structure but it is important that it be an appropriate convention. Both the fronts we have analysed are founded upon a tradition—the left-hand one makes use of experiments by Minoan, Egyptian, Greek and medieval builders, that on the right hand by Roman and Florentine builders; but since the structure is lintel the experiments in the expression of lintels are the appropriate experiments to study and apply.

An admirable experiment by medieval builders is shown in Fig. 170, a shop in Lisieux. Here the timber uprights express concentrated load and the braced horizontal members express the lintel system. The line of the centre pier is carried up and becomes a focus to the design for an artistic purpose.

There are times in the history of architecture when the artistic problems connected with structure are as urgent as the scientific. To-day we have to find a characteristic expression for concentrated loads and screen panels. This artistic plus scientific problem is the architects' job. When this duality is recognised in a problem and solved, in any building whatever, that building is also a work of architecture. Thus the finest works of "architecture" and "engineering" are indistinguishable. This is seen in many of the great works of engineering characteristic of the nineteenth century. The Forth Bridge by Baker, the Saltash Bridge by Brunel, are examples. The Menai Bridge by Robert Stephenson, "engineer," and Francis Thompson,¹ "architect" (Fig. 171) is also a grand achievement: there is not only a bold technique—the trains are run through a double series of large box girders—but there is true art in the emphasising and articulating of the structure, in a careful symmetry—unnecessary technically but most necessary artistically—and in a general neatness and grace. This joy in structure and neatness in expression is of the essence of architecture.

¹ "The external masonry of piers and abutments, in this bridge, is of mountain limestone known as Anglesey marble, obtained from the Penmon Quarries in Anglesey. The internal work is of Runcorn sandstone and a considerable amount of brickwork was used in the abutments and in the upper portion of the towers." From information supplied by the London Midland and Scottish Railway.



[By permission of the London Midland and Scottish Railway.

FIG. 171.—MENAI BRIDGE, ROBERT STEPHENSON AND FRANCIS THOMPSON.

Some Applications of First Principles x. 6.

The great "engineers" of the nineteenth century were often men like Brunel and Paxton who with a natural talent for architecture had concentrated upon structure and thus equipped themselves for the finest building achievements of their age. They were not engineers who took, now and then, to architecture, but architects specially concerned with structure. When Brunel had to build a water-tower for the Crystal Palace after its removal to Sydenham, he designed not one but two towers and placed them grandly as campaniles at each end (Fig. 82).

Thus we come to a first definition of an architect as a builder who desires the universal in his work.

APPENDIX

NOTE 1

Ch. ii. 1, p. 14

Climate directly influencing Simple Design.

Livingstone, in Central Africa on his Manyema expedition, writes:—"Our course was west and south-west through a country surpassingly beautiful, mountainous, and villages perched on the talus of each great mass for the sake of quick drainage. The streets often run east and west, in order that the bright blazing sun may lick up the moisture quickly from off them. The dwelling-houses are generally in line with public meeting-houses at each end . . . the roofs are low but well thatched with a leaf resembling the banana leaf but more tough, it seems from its fruit to be a species of Euphorbia. The leaf stalk has a notch made in it of two or three inches lengthways and this hooks on to the rafters, which are often of the leaf stalks of palms split up so as to be thin; the water quickly runs off this roof, and the walls which are of well-beaten clay are screened from the weather. . . . In some cases where the south-east rains are abundant the Manyema place the back side of the houses to this quarter, and prolong the low roof down, so that the rain does not reach the walls. These clay walls stand for ages. . . ." (Livingstone, *Last Journal*, 1st November, 1869.)

NOTE 2

Ch. ii. 9, p. 41

Planning of the "Basilical" Farm House.

"Its chief characteristic is that it unites in one body the space necessary for a very considerable establishment under one and the same roof, and therefore represents an extremely large building. Its ground plan is that of a basilica with nave and aisles. The middle always forms the so-called 'floor' (diele) (*a*), which is entered at the gable end through a large gate, and which goes through the whole house as far as the dwelling-rooms at the end. Owing to the want of an exit this door is used for backing wagons out. . . . In the forms of the Frisian and Saxon house generally in use the horses (*b*) and cows (*c*) are always so placed on both sides of the 'floor' that they are foddered from it. Over the 'floor,' over the cattle stalls, and over all the other rooms up to the ridge of the roof the corn harvest and hay harvest are stored on boards and poles laid between the joists. In the Saxon house the background of the 'floor' ends in a low hearth (*d*), on both sides of which are the bedsteads of the family arranged in a kind of narrow and rather high cupboard, whilst over against them, and near them, the men-servants sleep over the horses and the maids over the cows. To the right and left of the hearth extends the space used for the household (*e*), which is uninterrupted as far as the



FIG. *a*.—PLAN OF BASILICAL FARM HOUSE. (After Meitzen.)

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two opposite side walls of the house. This part of the house is lighted by high and broad windows, and on either side a glass door forms an exit into the open air. Usually, too, the well is inside the house at the side of the hearth.

"Thus the master of the house can superintend the whole management of the household from the hearth and his bestead, and hear every sound. So he exercises the fullest supervision, and so long as the smoke of the great hearth fire, which had no chimney, permeated the whole building, insects and the bad stench of the cattle were driven away, so that not till the most recent times was the need felt for building additional rooms behind the hearth-wall (heerwand). Of these rooms, (f) is usually the best room, (h) a living-room, and (g) a storeroom, kept dry by the fire on the hearth." (Meitzen, *Das Deutsche Haus*, p. 10.)

NOTE 3

Ch. iv. 5, p. 101

Desire of the Egyptian to prolong Physical Life.

The Egyptian houses and pavilions built (contemporary with the temples) in wood, clay, and wattle, survive for us only in drawings and funerary models. Those imitated in stone had necessarily to be modified in the course of translating into a different material. Hence arises what Capart calls the "optical illusion" in our view of early Egyptian architecture.

"Desiring for practical reasons to build for all eternity, without at the same time renewing all the traditional themes, the Egyptian architects were obliged to deform their works, and to make them heavier even to the point of modifying their character fundamentally. We might imagine, by way of comparison, the absurdity of a modern architect who persisted in the stone buildings, upon copying the forms combined in the architecture of a [contemporary] building of steel construction." (Jean Capart, *Egyptian Art*. Trans. by W. R. Dawson, p. 138.)

The anomaly is interesting as illustrating the fact that an architecture can only be understood by a close reference to the civilisation of which it is an expression.

The view of Egyptian culture to be gained from reading the encyclopaedic modern scholars offers an explanation of that preoccupation with the tomb which at first sight is a stumbling block to the student, but which lies at the beginning of Architecture. The Egyptian nobleman would not have been so concerned about his place after death if he had not greatly enjoyed his span of physical life. Professor Breasted says :—

"The Egyptian was passionately fond of nature and outdoor life. The house of the noble [see Fig. 1] was always surrounded by a garden in which he loved to plant figs and palms and sycamores, laying out vineyards and arbours and excavating before the house a pool lined with masonry coping and filled with fish. . . . This was the noble's paradise, here he spent his leisure hours with his family and friends playing at draughts, listening to the music of harp, pipe and lute, watching his women in the slow and stately dance of the time. Again in a light boat of papyrus reeds, accompanied by his wife and sometimes by one of his children, the noble delighted to float about in the shade of the tall rushes, in the inundated marshes and swamps. The myriad life that teemed and swarmed all about his frail craft gave him the keenest pleasure. . . . In this lighter side of the Egyptian life, his love of nature, his wholesome and sunny view of life, in spite of his constant and elaborate preparation for death, we find a pervading characteristic of his nature which is so evident in his art, as to raise it

Appendix

far above the sombre heaviness that pervades the contemporary art of Asia." (Breasted, *History of Egypt*, p. 89.)

Some writers on architecture have stressed the slavery upon which so much leisure and prosperity, as that of ancient Egypt, must have depended. But in the countless surviving illustrations of harvesting, ship-building, metal-working, marketing, in which the workers are represented, there is little indication that their existence was intolerable and to be happily escaped from by death. It is true that the ancient Pharaonic sign for *dominion* was a whip but the sign for *sovereignty* was a shepherd's crook.

NOTE 4

Ch. v. 6, p. 148

Renaissance Ideal of the Private House.

"The theme had some significance. The intent of those who dealt with it was to provide the man of the Renaissance with a fit setting for his life, and the spacious and lordly palace corresponded to the amplitude of the personality developed by the humanistic culture of the age. The representative man of the Renaissance may have missed certain of the higher ethical qualities, but he was many-sided, in mind and person a finely developed creature, self-reliant, instinct with vigour and set on mastery. Such a being demanded space and opulence with an air of greatness in his habitation, and fitly to house him was a task calling forth all the powers of the architects of the period. An imposing façade with heraldic achievements should proclaim his worth, wide gateways and roomy courts and loggie give an impression of lordly ease, broad staircases and ample halls suggest the coming and going of companies of guests. He would need a garden, where marble seats in ilex shades or in grottoes beside cool fountains should await him in hours when reflection or reading, music or conversation, called him awhile from keen conflict of wit or policy with his peers in the world outside. He would exact, moreover, that over all the place Art should breathe a spell to soothe the senses and to flatter pride; art sumptuous in materials, accomplished in technique, pagan in form and spirit, should people the galleries with sculptured shapes, cover walls and roof with graceful imagery, and set here and there on cabinet or console some jewel of carved ivory or gilded wood or chiselled bronze." (Baldwin Brown's *Vasari on Technique*, Notes on Architecture, p. 138.)

Compare Sir Henry Wotton—"Every man's proper mansion house and home, being the theatre of his hospitality, the seat of self-fruition, the comfortablest part of his own life, the noblest of his son's inheritance, a kind of private principedom; nay to the possessors thereof an epitome of the whole world; may well deserve . . . to be decently and delightfully adorned." (*Elements of Architecture*, Part II.)

NOTE 5

Ch. v. 10, p. 165

Sizes of Roman Bricks.

"Roman bricks were square, oblong, triangular, or round, the latter being used only to build columns in the Pompeian style. The square species comprises the *regulæ bipedales*,

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of 0.59 metre \times 0.59; the *tegulae sesquipediales*, of 0.45 metre \times 0.45; and the *laterculi bessales*, used in hypocausts, of 0.22 metre \times 0.22. Arches were built of a variety of the bipedales, of the same length, but only 0.22 in width, and slightly wedged. The triangular bricks were obtained by cutting diagonally a *tegula bessalis* with a wooden rule or a string, before it was put into the kiln. The largest bricks discovered in my time measure 1.05 metre in length." (R. Lanciani, *The Ruins and Excavations of Ancient Rome*, 1897, p. 39.)

NOTE 6

Ch. vii. 1, p. 231

Pitches of Doric Temple Roofs.

Temple of Ceres Paestum, hexastyle . . .	17° (Fragments Antiques)
Temple A Selinus, hexastyle . . .	14° (Hulot & Fougères)
Temple F Selinus, hexastyle . . .	16° " "
Temple G (Apollo) Selinus, octastyle . . .	14° " "
Parthenon, octastyle . . .	13.4° (Penrose)
Temple of Jupiter at Ægina, hexastyle . . .	15.5° (Cockerell)
Temple of Apollo at Phigalia, hexastyle . . .	14.7° "

NOTE 7

Ch. viii. 1, p. 270

On the Orientation of Building.

"And now we have to note a very interesting fact about the chief temples of Egypt, and, so far as we know—because the ruins are not so distinct—of Babylonia, and that is that they are 'oriented'—that is to say, that the same sort of temple is built so that the shrine and entrance always face in the same direction. In Babylonian temples this was most often due east, facing the sunrise on March 21st and September 21st, the equinoxes; and it is to be noted that it was at the Spring equinox that the Euphrates and Tigris came down in flood. The Pyramids of Gizeh are also oriented east and west and the Sphinx faces due east, but very many of the Egyptian temples to the south of the delta of the Nile do not point due east but to the point where the sun rises at the longest day—and in Egypt the inundation comes close to that date. Others, however, pointed nearly northwards, and others again pointed to the rising of the star Sirius or to the rising-point of other conspicuous stars. The fact of orientation links up with the fact that there early arose a close association between various gods and the sun and various fixed stars. . . . Not only is orientation apparent in most of the temples of Egypt, Assyria, Babylonia, and the East, it is found in the Greek temples; Stonehenge is oriented to the midsummer sunrise, and so are most of the megalithic circles of Europe; the Temple of Heaven in Pekin is oriented to midwinter. In the days of the Chinese Empire, up to a few years ago, one of the most important of all the duties of

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the Emperor of China was to sacrifice and pray in this temple upon midwinter's day for a propitious year.

The Egyptian priests had mapped out the stars into the constellations, and divided up the zodiac into twelve signs by 3000 B.C." (Wells, H. G., *Outline of History of the World*, 1920, pp. 139-141.)

NOTE 8

Chap. viii. 4, p. 276.

In the following diagrams the proportions of some of the standard examples of doors and windows are given.

In the appendix Fig. *b* the doors are drawn to a scale of English feet. The North Door of the Erechtheion is shown without the later inserted architrave, in which state the proportion is exactly two squares high. Mr Weir Schultz's drawing (*J.H.S.*, vol. xii., 1891) gives span between the original jambs as measuring just under 8 English feet: architrave 19½ inches. The proportion of architrave to span is thus approximately 1 to 4⅔.

The Temple of Hercules at Cori is taken from Donaldson's collection of Doorways, 1833. He gives the span in English figured dimensions as 7 feet 10 inches and architrave 1 foot 10½ inches: or approximately 1 to 4⅔, the proportion of the opening is slightly over two squares high.

The Pantheon door is taken from Cresy and Taylor, who also give figure dimensions in English feet—the span is some 4⅓ inches under 20 feet, architrave 2 feet 6 inches: the ratio is therefore just under ⅔th. The cornice is slightly more and frieze slightly less than the architrave. The ratios on the diagrams in the figure are given approximately.

The doorway to the Temple of Vesta at Tivoli is taken from Donaldson; the span is figured as 7 feet 10½ inches and architrave at the base as 1 foot 8.2 inches, or a ratio of 1 to 4.7. The architrave band itself in this door tapers slightly in its height, unlike the band of the Erechtheion.

The doorway to the Massimi Palace is taken from Donaldson; the span is figured as 6 feet 9½ inches, architrave 1 foot 2.1 inches, or a proportion of 1 to 5.8, or approximately ⅓th. The span of the opening is diminished by two inches at the top—the taper is emphasised by slightly reducing the dimension of the architrave also.

The Gibbs' examples are taken from Gibbs' *Rules for Drawing the Several Parts of Architecture*.

Fig. *c* is a sheet of windows giving proportions and drawn to a scale of English feet. The Cancelleria window is taken from Letrouilly's *Edifices de Rome Moderne*, in which are figured dimensions in metres. The span is 1.56 m., the architrave 0.205 m., giving a ratio of 1 to 7.6.

The Massimi window is taken from the Palais Massimi by Suys et Haudebourt, in which dimensions are figured in metres. The span is 1.51 m., the architrave 0.28 m, ratio ⅓th approximately.

The elevations of the windows of the Temple of Vesta at Tivoli are taken from Taylor and Cresy, in which are figured dimensions in feet. The interior has a span at the bottom of

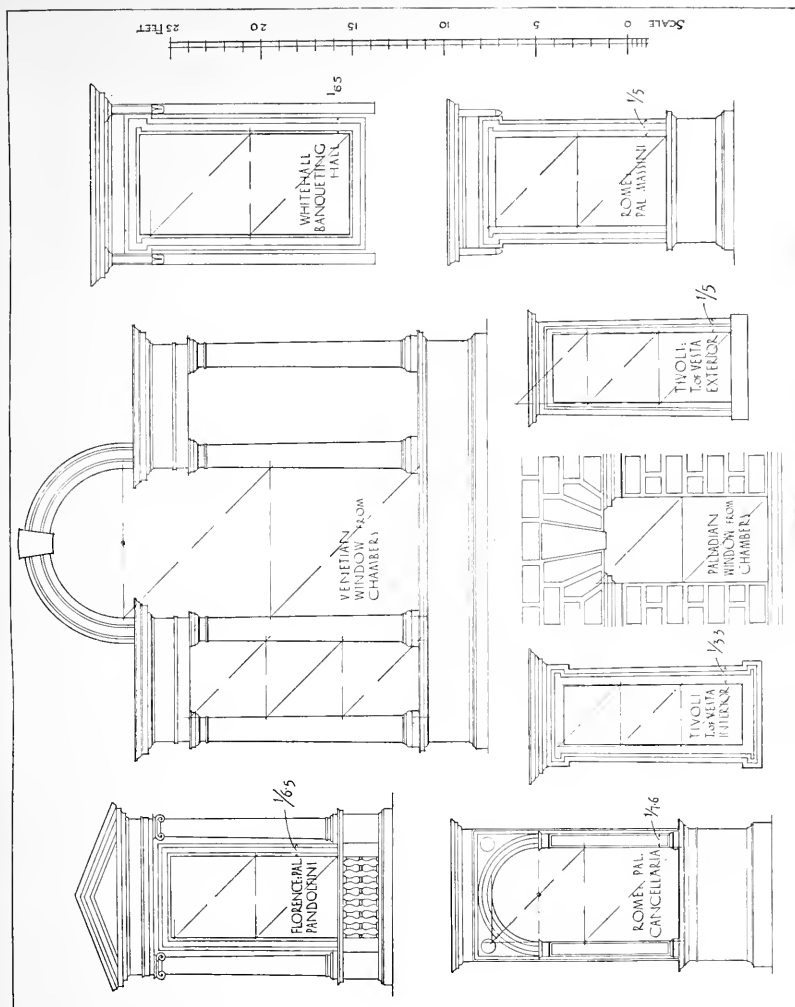


FIG. C.—PROPORTIONS OF WINDOWS. (For spans see text on opposite page.)

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3 feet 5 inches, architrave 11.9 inches, ratio 1 to 3.3. The architrave itself is diminished upwards. The exterior has span 3 feet 10½ inches, architrave 9.2 inches tapering upwards, ratio ⅓th.

The window from the upper tier of the Banqueting Hall, Whitehall, is taken from Vitruvius, *Britannicus*, vol. 1 : its span is 5 feet 6 inches, architrave 10 inches, ratio 1 to 6½.

The "Palladian" window is taken from Chambers : it is a type frequently occurring in the base floors of designs by Palladio and measures on his plates 4 Venetian feet, or approximately 4 feet 8 inches (English).

The window in Raphael's Pandolfini Palace is taken from Chambers, its span is approximately 4 feet 6 inches.

NOTE 9

Ch. ix. 6, p. 333

Early References to Sash Windows.

1519. "I have many prety windows shette with levys going up and down." (Hormanus, *Vulgaria*, 4to, 1519, fol. 244.)

1673. "Now I have engaged two excellent joyners, they are Germans (elsewhere described as Dutchmen), they have . . . made the double chasse for the windows." (Letter of Duke of Lonsdale to Sir William Bruce. Mylne's *Master Masons of the Crown of Scotland*, p. 186.)

1686-8. "Sarah Wyatt for a Sash Window and Frame with Weights, Lynes and Pulleys and a Wainscott Window-board done in the Governor of the Castles Secretaries Office, 70s. (Hope, St John, *Windsor Castle*, vol. i., p. 329.)

1699. "De Lorge : 'We had the good fortune here to find the Marshall himself. He showed us his great *Sash Windows* ; how easily they might be lifted up and down, and stood at any height ; which contrivance he said he had out of England by a small model brought on purpose from thence ; there being nothing of this *poise* in windows in France before,' near Montmartre." (Lister's "Journey to Paris," 1699, p. 191, *Notes and Queries Journal*, 1865.)

1699. "It has large sash windows throughout." (Walter Harris' description of the King's Royal Palace and Gardens at Loo, 1699.)

1773. The following from Johnson's *Tour of the Hebrides* (under "Banff") is also interesting :—"The art of joining squares of glass with lead is little used in Scotland and in some places is totally forgotten. The frames of their windows are all of wood. They are more frugal of their glass than the English and will often, in houses not otherwise mean, compose a square of two picces, not joining like cracked glass but with one edge laid perhaps half an inch over the other. Their windows do not move upon hinges but are pushed up and drawn down in grooves, yet they are seldom accommodated with weights and pulleys. He that would have his window open must hold it with his hand unless, what may be sometimes found amongst good contrivers, there be a nail which he may stick into a hole to keep it from falling."

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INDEX NOTE

Illustrations are indicated by italic type in the sub-heading and pagination.

THE Index includes names, places, and subjects in one alphabet.

Arrangement.—As a rule specific rather than general headings have been chosen, and classification avoided except in a few sub-indexes likely to be useful to students. Individual examples are indexed most fully under the name of the place where they are located and, when of sufficient importance, under their proper name also, *e.g.*—Athens, Propylaea, . . . Propylaea, Athens, . . .

Sub-indexes are given under each of the Elements dealt with:—DOORS, WINDOWS, ROOFS, ROOF CONSTRUCTION, WALLS, WALL CONSTRUCTION, and include both specific and general entries. As the book deals specially with the geological influences on building, the headings BUILDING STONE and QUARRIES have been sub-indexed geographically for use in connection with the map of building materials of Europe and the Ancient World, p. 31. Specific stones will also be found under their proper names in the index.

Plans, Elevations, Sections, are indicated by the word PLAN, ELEV., SEC., in Clarendon type. The word *foot.* after a page number refers to the footnote on that page.

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